3.6A

AN INTEGRATED FORECAST AND OBSERVING SYSTEM AT THE UNIVERSITY OF ALASKA FAIRBANKS

Jeffrey S. Tilley[1], Jeremy Krieger[1], John Dragomir[2], Xiande Meng [1], Michael R. Lilly[3] Kevin Engle'[1,4] and Virgil L. Sharpton [1,4]

[1]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775-7320

[2]National Weather Service Forecast Office, Fairbanks, AK 99775

[3]GW Scientific, P.O. Box 81538 Fairbanks, AK 99708

[4]Geographic Information Network of Alaska, Fairbanks, AK 99775

1. Introduction

Over the past year, we have initiated a collaborative effort among our respective institutions as well as the Alaska Department of Transportation to develop an integrated experimental system to ingest meteorological observations and provide a supplemental meteorological forecast capability within interior Alaska. The observations will consist of not only those available routinely from National Weather Service (NWS) sites (both manned and automated), but also from supplemental networks established within Interior Alaska through a data-sharing agreement.

The design of our system will not only make such observations available to the general public through a Web interface design, but also to incorporate these observations into a multi-grid hierarchy of forecasts and forecast products generated with the aid of a modified version of the Penn State University/National Center for Atmospheric Research MM5 model (e.g., Grell *et.al.* 1994; Chen and Dudhia 2001). The ultimate aims of the system are as follows:

- *to provide additional weather information in terms of observations and forecast products to the ADOT, other state agencies, the general and scientific public at-large, as well as NWS forecasters throughout the Alaska Region.*
- *to serve as a source of data and information for existing specialized high latitude research efforts, including field campaigns, and to serve as a springboard to promote new research ideas and efforts.*
- *to enhance existing NWS-Advanced Weather Information Processing Systems (AWIPS) capabilities and information via an 'off-cycle' emphasis for our forecasts and a Web-based delivery system.*
- *to aid in the development and evaluation of experimental products and model developments as part of our ongoing numerical weather prediction research efforts.*

In this paper, we describe our efforts to date, including the design methodology of the system, its current configuration and our plans for future development. While static imagery will be used for illustration in this paper, we will provide a demonstration of the various facets of the Web-based delivery system during the conference.

2. Data Sharing Aspects

At the heart of the success of this effort is the establishment of partnerships for the purpose of sharing and distributing various types of meteorological information. In relation to previous research projects, the 1st, 2nd and 4th authors had established working relationships with UAF's Geographic Information Network of Alaska (GINA). Primarily these relationships were for purposes of obtaining geostationary and polar orbiting satellite information for ingestion into and validation of an Alaska-specific research meteorological modeling system. The current system extends this collaboration by incorporating imagery as a part of a real-time modeling effort and as part of the entry interface.

Collaborative efforts on both research and educational fronts have been in place with the Fairbanks National Weather Service Forecast Office (Fairbanks WFO) for several years. Their contribution to this effort is the sharing of routinely collected surface observations from manned and automated land stations as well as ships and buoys.

The partnerships with a local scientific research and development company (GW Scien-

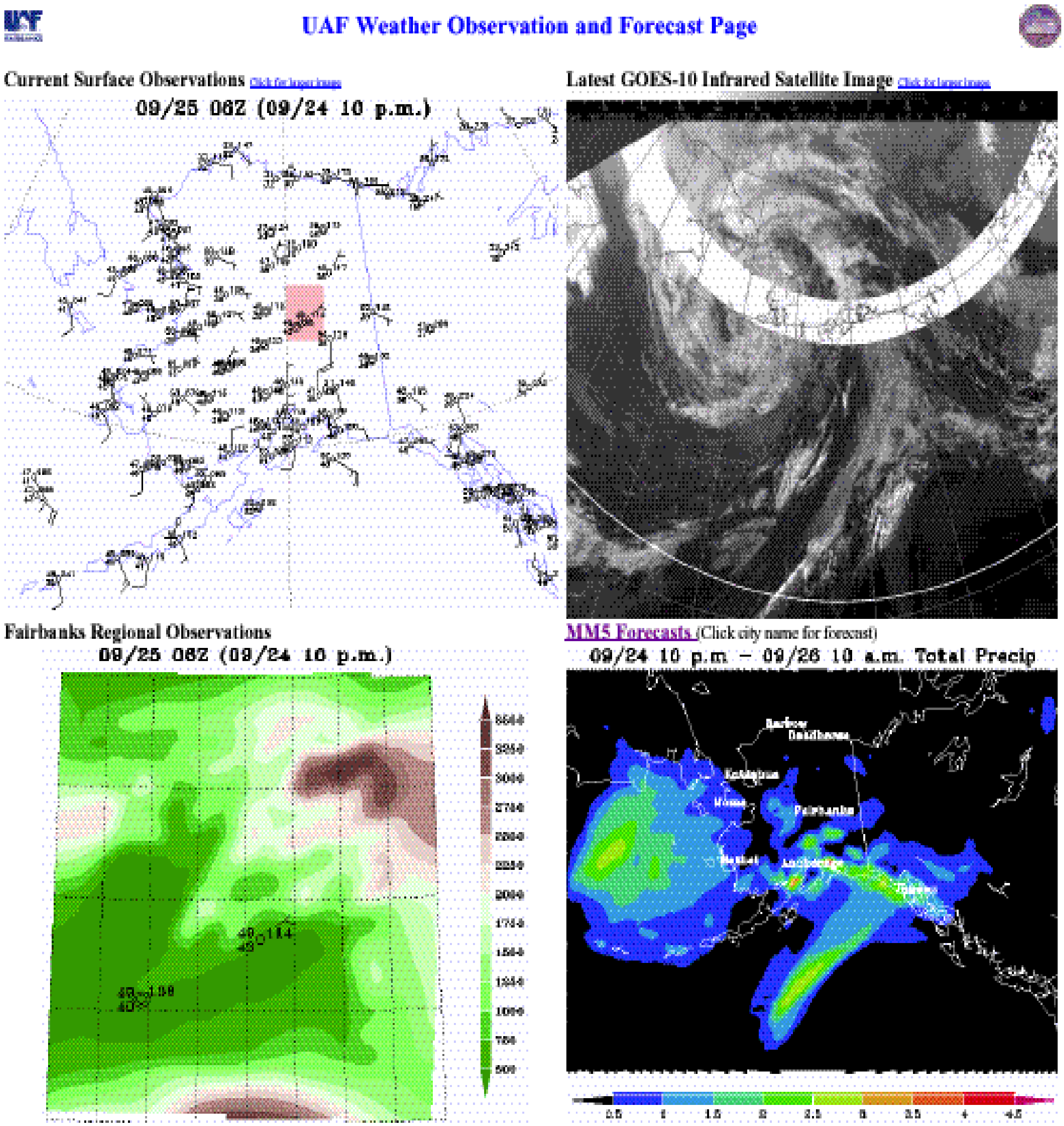


Figure 1. Entry level webpage interface for the University of Alaska Fairbanks (UAF) integrated weather observation and forecast system. The interface is divided into four primary panels beneath the title frame, which carries links back to the main UAF webpage (upper left icon) and Geophysical Institute webpage (upper right icon). The four panels are as follows: a) upper left---current surface observations for the state of Alaska and Yukon Territory, Canada; b) upper right---current satellite (visible or IR window channel) image of Alaska, obtained from UAF's Geographical Information Network of Alaska; c) lower left---local Fairbanks surface observations; d) PSU/NCAR MM5 forecast accumulated precipitation (colors, cm) for the time indicated for the statewide region, as well as links to local city forecasts and the main UAF MM5 Forecast Page, shown in Figure 2.

ific) and with the Alaska Department of Transportation (ADOT) have been more recent, but show the potential in becoming a focal point for the development of an enhanced statewide observational network. GW Scientific (GW) has established a series of primarily hydrologic stations in interior Alaska, with the bulk of these stations in the Fairbanks vicinity. With the addition of some sensors and a few additional stations strategically placed to supplement the existing observations, a first cut at a mesonet of stations in Fairbanks will be realized. GW has also been instrumental in the forging of the partnership with the ADOT, which is implementing a network of Road Weather Information Systems (RWIS) using both state and federal funds. UAF is contributing supplemental instrumentation to several of these stations to allow them to be more useful for ingest in and validation of meteorological models such as the modified MM5 system to be discussed in the next section.

As of this writing, we are in discussions to find ways of extending these partnerships in the development of an expanded statewide mesoscale surface observation network, with the ultimate goal of developing a facility similar to MESOWEST (Horel *et al* 2002) at the University of Utah. Such a system may eventually include observations of ocean as well as atmospheric properties given the clear importance of the state of the ocean for the marine atmospheric environment that surrounds Alaska. Progress on these fronts will be reported in future papers.

3. Interface Design

3.1 General Comments

Figure 1 illustrates the present prototype entry interface for the public, as of this writing. It can be found on the Web at http://knik.iarc.uaf.edu/AtmGroup/akweather.htm. There are four main components to this interface involving observational and modeling data., each of which will be discussed in turn in subsequent subsections. Here we briefly note that our initial underlying philosophy for the interface is to be able to provide, at a glance, basic information on surface weather conditions statewide and in the Fairbanks area as well as forecast conditions over a 36-hour period on multiple scales. The basic interface is not intended to be comprehensive, but instead to allow for users of various levels of sophistication to obtain useful information. This philosophy has been only partially implemented in the web interface design as of this writing. The interface itself is expected to evolve dynamically over time in response to feedback from various users and user groups.

In the following four subsections we touch on each aspect of the initial web interface, including description of more detailed information available from deeper web levels of the facility. As appropriate, we will also describe technical aspects of the sources of information displayed.

3.2 Statewide Surface Observations panel

The primary content of this panel of the page is a regularly updating plot of surface observations from a selected subset of all available NWS land stations, ship reports, buoy reports, and RWIS stations. Viewing a subset of the various observation types is required on this scale given that there are several regions in which observations are clustered too close in space to allow for legible plotting. Note, however, that users can click on the "larger image' link at the top of the plot to obtain a larger -sized version of the plot, if desired.

The standard WMO station model conventions are adopted, and observations of temperature, dewpoint, sea level pressure and winds are plotted. Information on clouds and present weather is currently not included for the sake of plot legibility. To accommodate potential users not familiar with the WMO station model conventions, we are in the process of constructing an appropriate information module on the station model. This will be included on the plot as a button which, when accessed, will bring up a new window with a summary of the station model and its interpretation.

Observations are currently updated on an hourly frequency. The rationale for the choice lies in two facts: first, due to communications constraints and the requirement to prioritize communications towards needs of the operational forecasters, NWS transmits surface observations to the UAF facility on an hourly frequency.

Second, many potential users of the site are generally used to accessing NWS observations at hourly intervals, from either the NWS Alaska region office websites themselves or from a commercial provider such as The Weather Underground™. Given that much of the year special stations reports occur only rarely and may be difficult to determine from a statewide plot, the choice was made, as a starting point, to limit the update frequency to hourly, consistent with the frequency that the users are most accustomed to. This policy may change in the future and does not necessarily hold for the finer scale observations discussed in section 3.4

3.3 Alaska Regional Satellite Image panel

This panel contains the most recent geostationary infrared window channel image from the GOES-10 satellite platform, transmitted via the GINA facility from a pre-existing GOES downlinking station at the NWS Alaska Region headquarters in Anchorage. No color enhancement curves are utilized on this image and thus the approximate temperatures at a given pixel are shown in terms of a greyscale: black represents the warmest temperatures in the image (generally warmer than about 15-20^{o}C) while the white areas represent temperatures colder than approximately -45^{o}C). Although the nominal resolution of the infrared window bands (4km) is coarser than that of the visible bands (1km), the overall utility of this channel is greater due to the large variability in high latitude daylight conditions over the annual cycle. Indeed, for much of the winter "polar night", the visible channel is useful for under 8 hours per day (and less than 6 at the winter solstice).

Another choice made was the decision to utilize geostationary rather than polar orbiter imagery for the display. This choice was motivated primarily by the fact that without cloud information in the statewide surface observations panel (section 3.2), it was desirable to have a synoptic depiction of cloud cover via satellite that was temporally consistent with the surface observation plots. Although the number of polar orbiting satellites, and thus the frequency of passes over our area of interest, has recently increased, as yet there are no products blending NOAA-series Advanced Very High Resolution Radiometer (AVHRR) and NASA-series (i.e., "Terra" and "Aqua") Moderate Imaging Spectroradiometer (MODIS) datasets in real-time for the high latitudes. If such products do become available in real-time then it is possible that such products would replace the geostationary image currently utilized in the web interface.

3.4 Additional Mesoscale Observations: Fairbanks

Primarily to stimulate local interest in mesoscale observations from both an operational and a research perspective, we are initially planning for the lower left panel of the web interface to display available NWS, RWIS/ADOT and GW Scientific/UAF observations within approximately a 60 km radius of Fairbanks. These observations, which comprise a subset of the full set of currently planned supplementary observations (see Figure 2), will be updated at intervals as frequently as 15 minutes. For display purposes in this paper, only two stations from the standard NWS network are plotted. At a future date we will consider expanding the coverage of this panel to include the entire set of supplementary observation sites shown in Figure 2.

3.5 MM5 Model Forecasts

3.5.1 Overview

The lower right panel on the web interface shows a sample precipitation forecast for Alaska and adjacent regions of Canada, Russia, the Arctic Ocean and the North Pacific Ocean. The forecast covers a 36 hour period, specifically the period listed at the top of the plot, with accumulated precipitation during the entire period, in cm, plotted according to the color scheme at the bottom of the plot.

The plot is updated according to the forecast cycles we have adopted for our local UAF MM5 real-time system. Two cycles, initiated at 06 UTC and 18 UTC, are conducted per day. The initial and boundary conditions for the model are derived from the corresponding run of the NCEP Eta model run specifically over this region for use by the NWS Alaska Region forecasters. The data is transmitted from NCEP to the Alaska Region NWS headquarters in Anchorage and reflected to each of the forecast offices as a series of netCDF files. As these files are received by the Fairbanks WFO, they are immediately reflected to our UAF Origin 2000 server and automatically converted into a suitable format via the standard MM5 preprocessor suite (e.g., Dudhia *et al*, 2002; Guo and Chen 1994). Available observations (from only the NWS at the time of this writing; other sources will be included over time as appropriate) are ingested into the model as well via a set of automated script procedures. The model is then executed on the domain indicated in Figure 1 for a 36-hour period. Forecasts on a suite of nested domains, illustrated in Figure 3, are also produced. All domains utilize 41 vertical sigma-coordinate levels.

A link is located as part of the panel name for the MM5 forecasts on the entry Web interface. This link takes the user to a separate MM5 Forecast Products web page (http://knik.iarc.uaf.edu/AtmGroup/ForcastGraphics.htm)from which much more detailed forecast information is available via a variety of output forecast products. Further discussion on these products is given in section 3.5.2.

In addition, a small subset of Alaskan locations are located on the precipitation plot. While this information provides some geographic context, the city or town names are actually clickable objects which, when activated, will produce a pop-up window with a text forecast for that location for the next 36 hours. These text forecasts are derived solely from the MM5 model outputs. In their initial implementation they will be fairly simple algorithms; over time we intend to gradually increase the level of sophistication as an area of active forecast research.

The MM5 model configuration, in terms of physical parameterizations and options utilized in the real-time modeling system has been undergoing steady revision since the system was brought on-line in May 2002. Changes to the model configuration that have occurred since that time reflect work done by researchers at UAF, the National Center for Atmospheric Research, Ohio State University and the Air Force Weather Agency to improve MM5 performance for cold season and/or high latitude applications. Table 1 lists the current configuration of the model as of this writing (October 2002). Additional changes since October 2002 will be discussed at the talk during the conference.

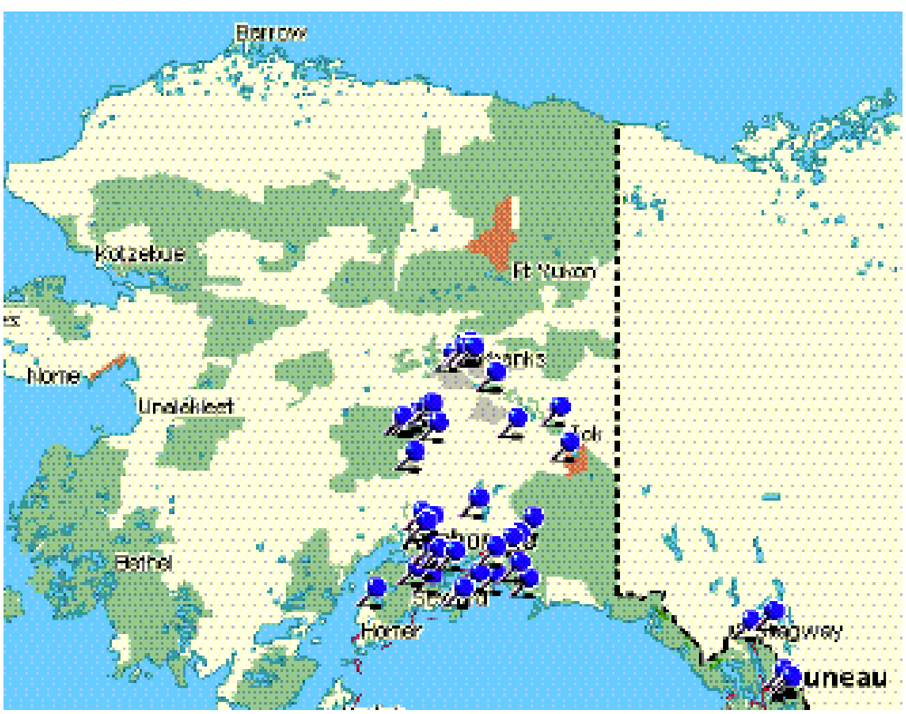


Figure 2. Spatial distribution of supplementary surface observation stations (blue push-pin symbols) to be obtained through data partnerships with GW Scientific and the Alaska Department of Transporation and Public Facilities. Note that the network is primarily confined to areas accessible from the Alaska road system.

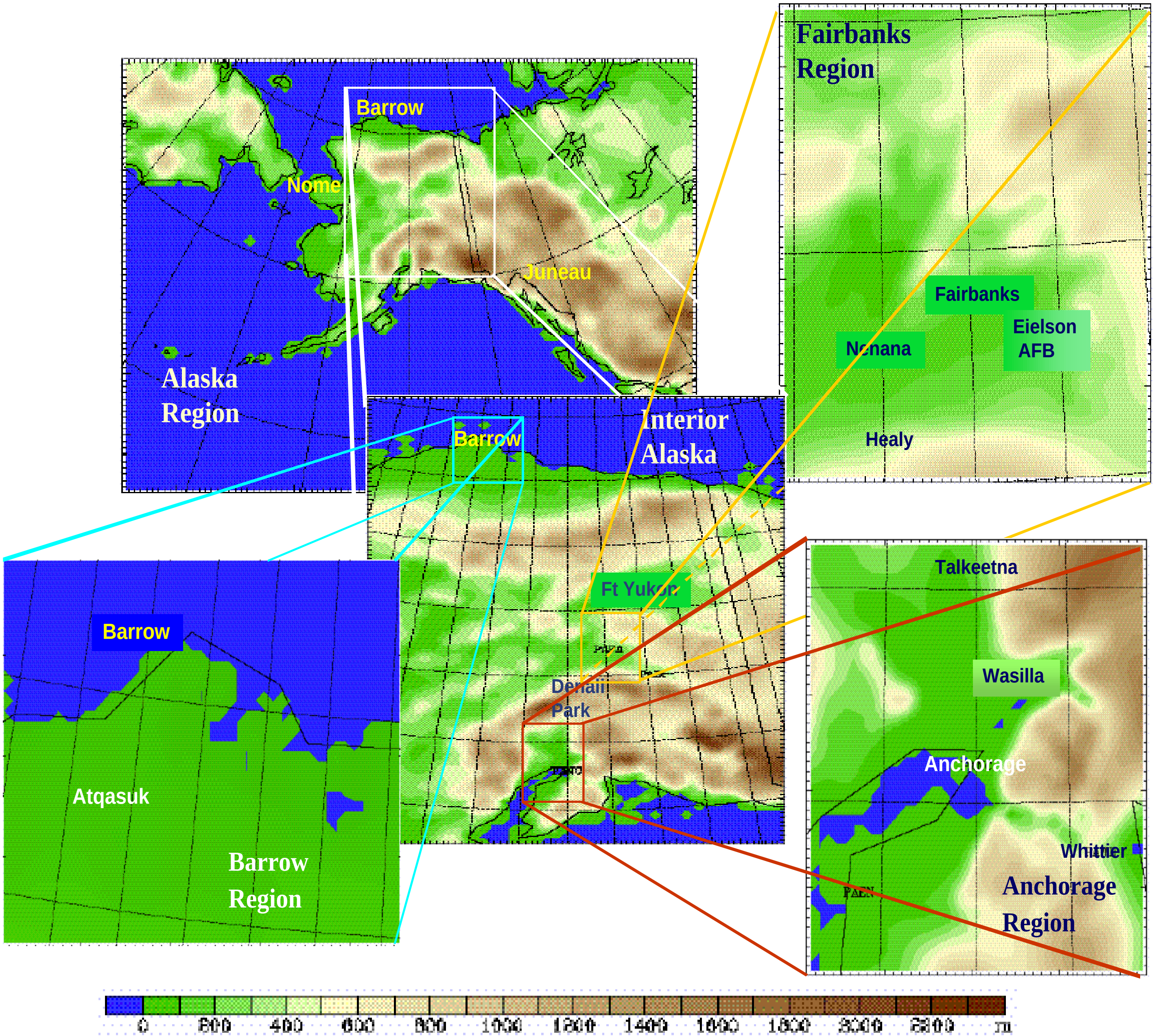


Figure 3. Domain configurations and terrain utilized in the real-time MM5 modeling system. The outermost domain (Alaska Region) resides on a 45km horizontal grid and is executed for 36 hours. The Interior Alaska donain , with a grid resolution of 15 km begins execution at 6 hours into the forecast cycle and continues until 30 hours. The Interior Alaska Domain is the mother domain for the remaining three nested domains: the Fairbanks Region, Anchorage Region and Barrow Region domains. All of the innermost domains reside on a 5 km horizontal grid and begin execution at 9 hours into the forecast period, ending at 24 hours. The color scale indicates the elevation of a grid box, in meters. 2-minute USGS terrain data are utilized for all domains.

3.5.2 Sample Products

If a user clicks on the link "MM5 forecasts on the Web interface, the user is taken to a separate page which lists the various MM5 forecast products which are available. Figure 4 illustrates a sample of such a page. Forecast products are organized by product name and the domain of interest (e.g., Alaska Region, Interior Alaska, Fairbanks, Anchorage, Barrow). In addition, near the top of the page information is provided on the time stamp of the latest forecast cycle available and, through a separate freeware widget available from Weather Underground, Inc., the current Fairbanks time and temperature.

Each of the names of the various forecast products (really MM5 native or postprocessed fields) is a clickable link. When activated, a new pop-up window will appear containing an information file in PDF format. These files are intended to help general scientific users of the site to better understand the nature of the particular forecast product in question. They should also be useful for members of the general public with some scientific background. The authors welcome feedback on these files and will make appropriate modifications as deemed appropriate from such feedback. One change that was made in direct response to such feedback was the inclusion of a direct link to Adobe Systems, Inc. site where a user who does not already have access to Adobe's Acrobat Reader™ product can download a freeware version of the product in order to read the informational files.

It is also important to note that the domain designations on the MM5 Forecast Graphics page are also clickable links. Activating a link will result in the creation of a new pop-up window that shows a graphical depiction of the topography of the domain chosen, and, for all but the Alaska Region domain, a representation of the relative position of that domain with respect to the others, through a numerical key. The Alaska Domain is designated Domain 1 while the Interior Alaska domain is Domain 2. The Fairbanks Domain is designated Domain 3, and so on.

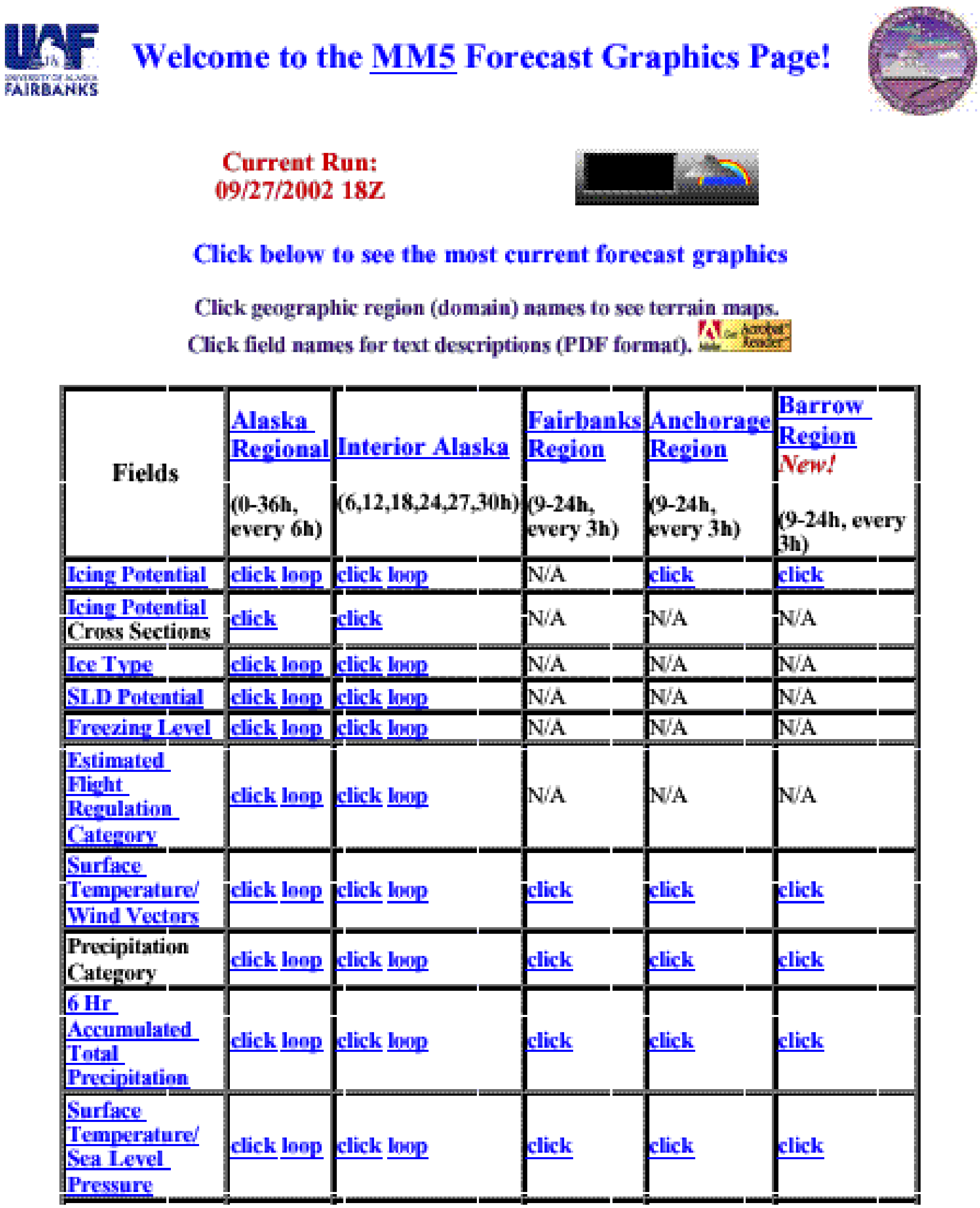
The hours that forecast products are available for a given domain are listed at the top of each column. All products are available as a series of plots, one for each forecast time listed, and can be accessed by clicking on the "click" link for the particular product/domain combination desired. Some products are also available as animated loops by activating a "loop" link. In both cases, link activation results in a pop-up window being generated that contains either the series of graphical images or the animated loop. All graphical images available from this page are generated using the MM5 postprocessor *RIP* (Read, Plot, Interpolate) written by M. Stoelinga

Table 1: UAF Real-Time MM5 Configuration

Physical Process	Scheme Utilized
Cumulus Convection	Grell (1993)
Explicit Microphysics	Reisner *et al* (1998) mixed phase modified following Cassano *et al* (2001)
Radiative Transfer	CCM2 scheme modified following Cassano *et al* (2001)
Land Surface	NOAH-LSM (Koren *et al* 1999) implemented as in Zhang and Tilley (2002)
Boundary Layer	MRF (Hong and Pan 1996) scheme
Data Assimilation	MM5 standard Newtonian Nudging (Stauffer and Seaman 1990)
Initialization	Operational Alaska version of the NCEP Eta Model
Postprocessing Algorithms	UAF IIDA (Tilley *et al* 2002); Skill score-based verification

of the University of Washington (Stoelinga, 2001). Figures 5a though 5d illustrate plan view plots created by this package for standard MM5 output variables on the Alaska Region and Interior Alaska domains. We have not only included variables such as temperature, winds and precipitation that have direct forecast value to the public-at-large, but also some additional variables (integrated cloud water, omega vertical motion, heights/vorticity) that have been deemed as potentially useful to the NWS forecasters in the Alaska Region.

In addition to standard MM5 output variables, we have the capability of producing further diagnostics using a variety of algorithms, some of which are standard features of the *RIP* package (e.g., the Flight Regulation category) and others which have been developed locally (e.g., precipitation category) or in conjunction with other investigators. The prime example of this



Welcome to the MM5 Forecast Graphics Page!

Current Run:
09/27/2002 18Z

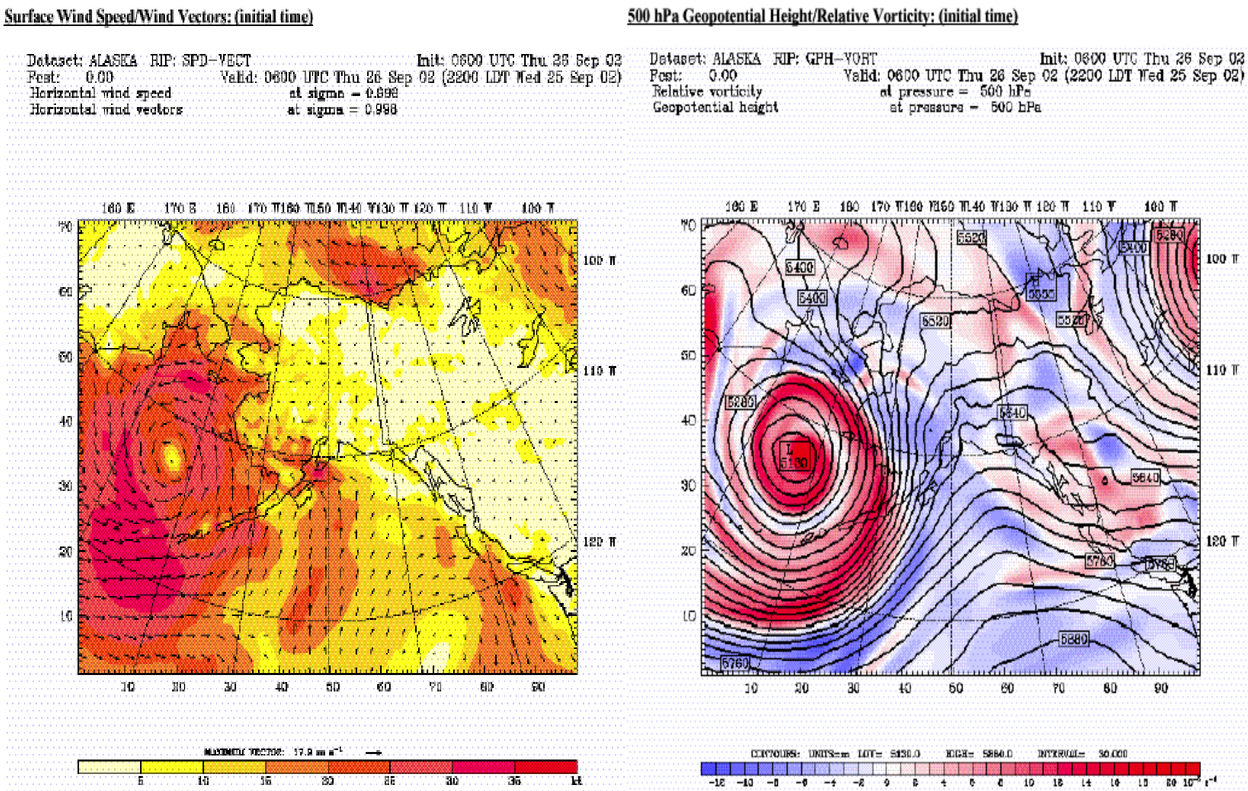
Click below to see the most current forecast graphics

Click geographic region (domain) names to see terrain maps.
Click field names for text descriptions (PDF format).

Fields	Alaska Regional (0-36h, every 6h)	Interior Alaska (6,12,18,24,27,30h)	Fairbanks Region (9-24h, every 3h)	Anchorage Region (9-24h, every 3h)	Barrow Region New! (9-24h, every 3h)
Icing Potential	click loop	click loop	N/A	click	click
Icing Potential Cross Sections	click	click	N/A	N/A	N/A
Ice Type	click loop	click loop	N/A	N/A	N/A
SLD Potential	click loop	click loop	N/A	N/A	N/A
Freezing Level	click loop	click loop	N/A	N/A	N/A
Estimated Flight Regulation Category	click loop	click loop	N/A	N/A	N/A
Surface Temperature/ Wind Vectors	click loop	click loop	click	click	click
Precipitation Category	click loop	click loop	click	click	click
6 Hr Accumulated Total Precipitation	click loop	click loop	click	click	click
Surface Temperature/ Sea Level Pressure	click loop	click loop	click	click	click

Figure 4. Sample of the upper half of the MM5 Forecast Graphics page discussed in text. Several fields are omitted from the lower part of the figure for clarity and legibility. See discussion in section 3.5.2 for details.

latter type of product can be seen in the products designated *Icing Potential, Ice Type and SLD Potential*. These products are the result of recent work at UAF to adapt, for high latitude application, the NCAR/RAP icing algorithm (e.g., McDonough and Bernstein 1999) now utilized as CIP (current icing potential) by the Aviation Weather Center in Kansas City (M. Politovich, per. comm.). A description of our work to adapt the CIP as it is utilized here, as the so-called UAF



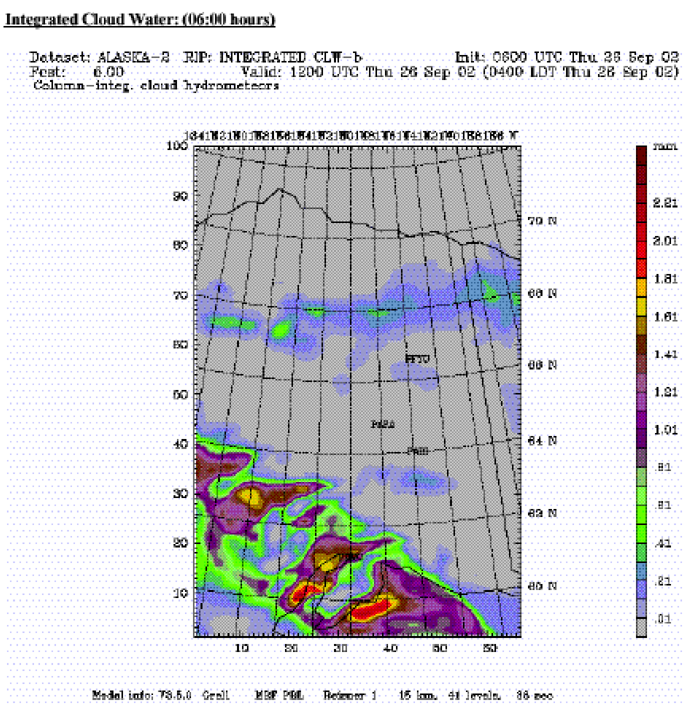


Figure 5. Samples of forecast products reachable from the MM5 Forecast Graphics page a) Surface wind speed (colors; kts) and direction (vectors) at the model forecast initial time (06 UTC 9/28/02) on the Alaska Region domain; b) Geopotential height (contours; m) and relative vorticity (colors; s^{-1}) at the 500 hPa level for the same time and domain as part a; c) Vertically-Integrated Cloud Liquid Water (colors; mm) for a 6 hour forecast (12 UTC 9/28/02) on the Interior Alaska domain, initiated as part of the same forecast cycle as parts a) and b).

Integrated Icing Diagnostic Algorithm (UAF IIDA) can be found in Tilley *et al* (2002). Here we summarize by noting that the UAF IIDA, in its diagnostic mode, incorporates surface observations and satellite observations from the GOES Imager and AVHRR sensors in addition to the MM5 output fields. In its forecast mode, the UAF IIDA is based solely on MM5 output. A sample plot of an *Icing Potential* product is shown in Figure 6.

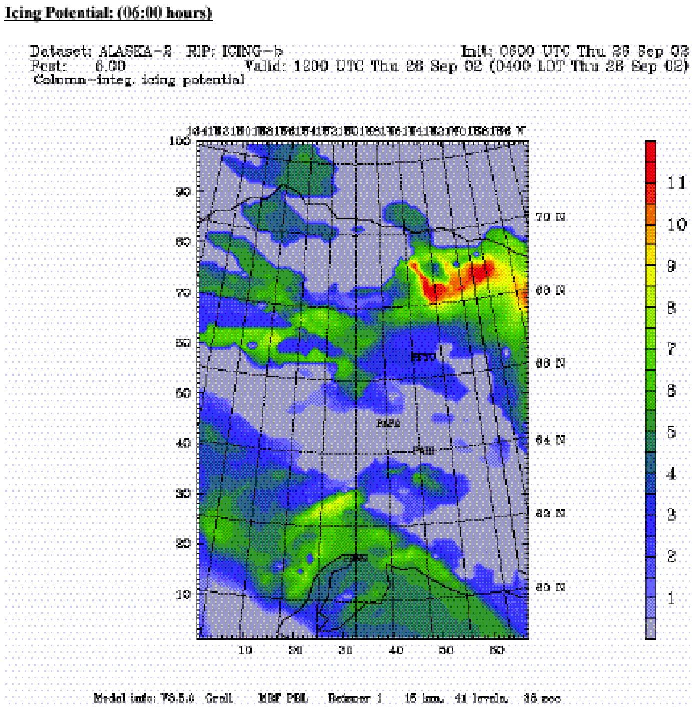


Figure 6. Sample Plot of UAF IIDA Icing Potential Forecast/Diagnostic Product on the Interior Alaska (15km) domain. While the Icing Potential itself is a 3-dimensional quantity, for economy of presentation we utilize a vertically-integrated form of the Icing Potential derived by summing the Icing Potential through the grid column. Maximum value for the vertically-integrated field is 20. Field shown is for a 6 hour forecast valid at 12 UTC 26 Sept 2002) from the forecast mode of the UAF IIDA. In forecast mode the Icing Potential field is derived essentially from the MM5 model simulation alone.

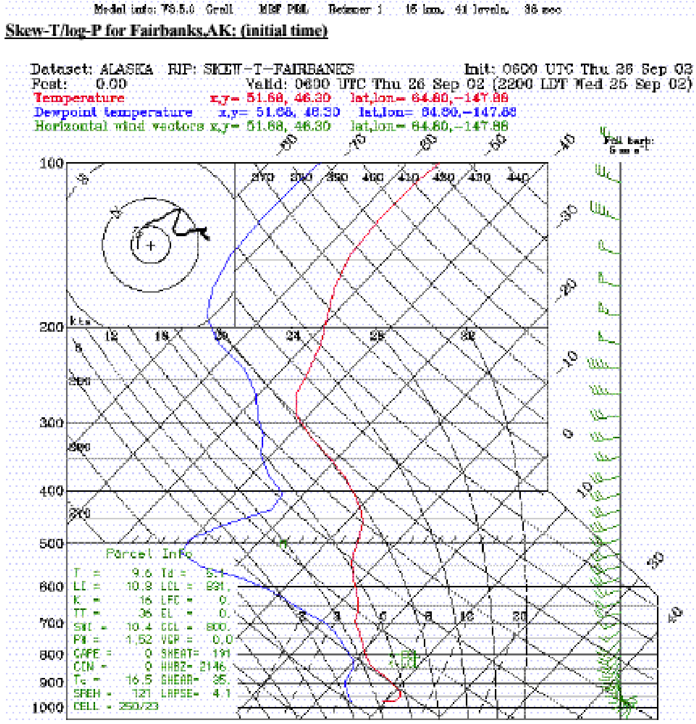


Figure 7. Sample vertical sounding plot for the MM5 45 km (Alaska Region domain) model gridpoint centered on the location of the Fairbanks International airport. The sounding is plotted on a standard skew-T/log P thermodynamic diagram. The temperature profile is shown by the red line while the dewpoint profile is shown by the blue line. Wind barbs are plotted in green, with a wind hodograph in the upper left corner. Note that the system allows for sounding plots to be derived from any of the applicable model domains, in this case the Alaska Region, Interior Alaska and Fairbanks Region domains. Since the grid boxes corresponding to the Fairbanks airport for the three domains vary in resolution by a factor of nine, some differences in the sounding representations from the three grids is expected and can be used as a means of better understanding the impacts of mesoscale topography on the vertical profile.

Besides the plan view type of plots discussed above, we also have the capability through the RIP package of plotting fields to show their vertical structure. A common application in this regard is model forecast vertical soundings of temperature, wind and dewpoint on Skew-T/log-P thermodynamic diagrams. An example of such a plot for Fairbanks is illustrated in Figure 7; the plot follows standard Skew-T/log-P plotting conventions for the temperature, dewpoint and wind fields, but also includes a hodogram of the winds in the upper left of the figure. Further, the plot provides information on the possibility of convective activity through a variety of computed convection diagnostic indices, including the commonly used computation of convective available potential energy (CAPE). During the warm season we also provide plan view plots of CAPE for the various domains as an aid to forecasters and more sophisticated aviation users who are experienced at interpreting horizontal distributions of CAPE.

In addition to the ability to plot variables in vertical profiles at a point, the RIP software also provides the ability to plot fields in vertical cross section. In our present implementation, we have elected to limit such plots to the UAF IIDA Icing Potential diagnostic. This is partly because aviators have expressed a desire for this type of information in an icing diagnostic, and partly for intercomparison purposes with a slightly different Alaska-specific algorithm developed at NCAR.

We wish to strongly stress at this point that all the UAF IIDA-related products are still highly experimental at this stage and should not be relied on as official aviation weather guidance. Such guidance is properly obtained from the Alaska Aviation Weather Unit (AAWU) in Anchorage. This fact is clearly stated on all our UAF IIDA-related pages, including direct hyperlinks to the AAWU site (http://aawu.arh.noaa.gov).

4. Future Development

Over the next 6 months we anticipate additional development on several aspects of our system. Most notable will be the addition of the remaining observational station locations seen in Figure 2 that are not yet available within our real-time system. The increase in station density will allow for an improved depiction of mesoscale conditions in the Fairbanks vicinity as well as interior Alaska.

Second, further improvements to the MM5 model are planned, including the capability for assimilating AVHRR cloud information through either the currently available Newtonian nudging approach or via an intermittent data assimilation methodology (Fan and Tilley, 2002). Also available in a research mode is a coupled sea ice/ocean mixed layer model which should prove useful for improving the accuracy of wintertime simulations. A constraint in the incorporation of these effects lies in the fact that our in-house computing capacity is not what is normally available at any operational center. As a result, each improvement to the system carries a cost that serves to significantly slow down model performance. Since such a real-time model loses its usefulness once the wall clock time for a forecast becomes too large, we will be weighing the incorporation of new features against their relative computational cost.

Finally, as news of our system spreads and the user base increases, we anticipate making cosmetic and/or informational content changes on the series of web pages and graphical products available, based upon feedback from the users. It is our hope that through such feedback we can develop a system that provides a true service to the general public within Alaska as well as to the Alaskan aviation community, NWS forecasters, scientific researchers and the numerical forecast community at-large.

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