9.2 Aviation Weather Forecasts beyond Today

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1. INTRODUCTION

Aviation weather forecast information has traditionally been focused on today's weather. Airport weather forecasts (TAFs) are for 24-30 hours into the future. The aviation weather hazards forecasts (AIRMETs, SIGMETs, CCFP, Area Forecasts, and related guidance products) generated by the National Weather Service (NWS) Aviation Weather Center (AWC) (available at http://aviationweather.gov) are typically for periods of 12 hours or less into the future. While the current products are critical for air traffic control and safe flying today, there is a lack of information available for flight planning beyond today. This longer range planning is especially critical for General Aviation (GA). If a GA pilot does a cross country flight today, will they be able to return tomorrow? Should the GA pilot rent an airplane for flying this weekend, or will the weather be unfavorable for flying? There is a need for aviation forecasts beyond today.

2. FORECAST MODELS

Other segments of weather forecasting have been steadily increasing the forecast times of their products. Severe weather forecasts are available for three days into the future. Public weather forecast products now provide forecasts of precipitation, temperature, winds, and clouds out to a week into the future. These increases in forecast times have been made possible because of improvements in the numerical forecast models.

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The NWS National Centers for Environmental Prediction (NCEP) routinely runs a suite of numerical forecast models. The Rapid Refresh Model (RAP) is run hourly with forecasts out through 18 hours. The RAP is the primary model used for aviation weather automated diagnostics, such as the Forecast Icing Prediction (FIP) and the Graphical Turbulence Guidance (GTG) available from the AWC. The North American Model (NAM) is run every 6 hours with forecast out through 84 hours. The NAM is used primarily for precipitation and severe storm forecasts, such as those from the Storm Prediction Center (SPC). The Global Forecast System (GFS) provides global forecasts out through two weeks into the future.

While the NAM and GFS models have been developed primarily to support public weather forecasts, the model grids can be adopted to provide aviation forecasts. For instance, the models need to generate clouds for the radiation budget calculations needed for temperature forecasts (cloud reflect sunlight from the top and reradiate long wave radiation from the bottom). The models have grids of cloud tops, cloud bases (in pressure coordinates), surface pressure, and fractional cloud cover. The cloud bases in pressure coordinates can be converted into heights above ground using the hypsometric equation.

The North American Model (NAM) forecast grids provides a large suite of model forecasts of meteorological state parameters (such as winds, temperatures, etc.) and parameterization grids (such as clouds amounts, turbulent kinetic energy (TKE), etc.), which can be used to generate aviation forecasts. Using the NAM model grids, a suite of aviation weather forecasts have been generated with forecast times every 3 hours out to 84 hours into the future. The available products include ceilings, visibility, cloud tops, mountain obscuration, boundary layer turbulence, boundary-layer depth, wind gusts, low-level wind shear, thunderstorms, simulated radar, density altitude, sea-level pressure, icing-base height, clouds and winds aloft. These products are publically available at the Embry-Riddle web site of http://fltwx.db.erau.edu/aviationfcst.php and http://fltwx.db.erau.edu/fcstsAloft.php. The products are displayed as a loop of 27 images with 3 hours between images resulting in a loop of 3+ days of forecast images. The loops are displayed with the Javascript software SciAnimator (see http://github.com/brentertz/scianimator) which allows the looping on a variety of displays including mobile devices.

3. FORECAST IMAGES

The aviation weather displays at the above web site are somewhat different than traditional weather forecast displays. Model and observational data have traditionally been displayed as graphics. Satellite and radar data have traditionally been displayed as images. All of these data fields are originally just numbers. The display techniques are used to help people make sense of the numbers by putting them into an image format. The big difference between the graphical displays and image displays has been the original data resolution. Graphical display techniques are typically used for data sets on the order of 100 points in each direction. Image display techniques are typically used for data sets on the order of 1000 points in each direction. Weather forecast models have traditionally been displayed with graphical techniques. However, the size of the model data sets has been increasing, and is starting to approach the resolutions of traditional image data sets. For instance the NWS North American Model (NAM) output grid has 428 rows by 614 columns. The traditional method of contouring a grid to make a picture is to draw lines of equal (iso) values. The interpolation between grid points for the isoline allows the resultant picture to have a higher spatial resolution than the original gridded data. The traditional method of making an image is to transform each data pixel into an image pixel. Most computer display systems have 8 bit displays, so the data value is scaled to fit within the 0 to 256 brightness range. For contoured graphics, the area between contours can be colored the same color as the contour. Most computer displays support polygon objects, so the filled contour can be presented as polygons to the screen display. Typically filled graphics will support around 32 different colors of graphics. Converting model data into images rather than graphics allows for the user to see a wider range of structure in the data as well as being able to display fields with widely varying values. Consider the following example. Figure 1a and 1b show the 24 hour forecast of surface visibility valid at 12Z Nov. 18, 2014. Figure 1a is shown as a contour while 1b is shown as an image.

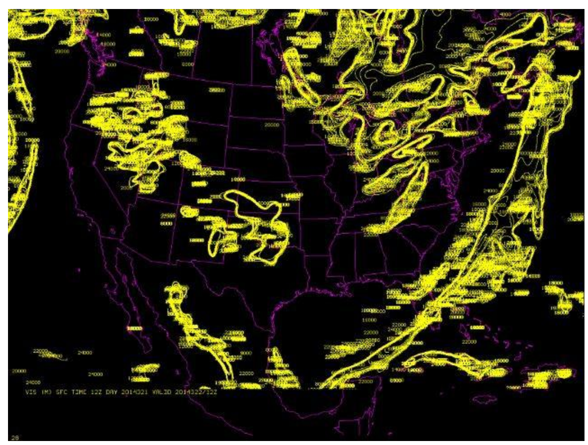

Figure 1a. *Contoured display of surface visibility valid at 12Z Nov. 18, 2014. Contours are every 200 meters.*

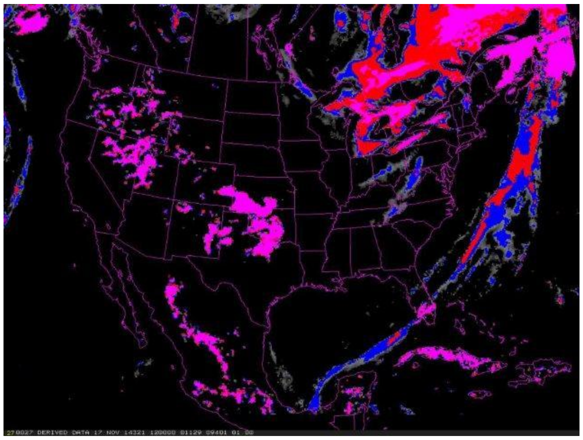

Figure 1b. Image display of model grid of surface visibility from the same grid as the figure 1.a graphic above. Image values have been converted to gray scales which are then colored to show MVFR, IFR, and LIFR conditions.

Since visibility is not a continuously varying phenomena, the contoured display of figure 1a has tightly packed contours, making it difficult to interpret the display. Making the data into an image in figure 1b makes the data much easier to interpret.

The data processing and image generation were done using the McIDAS X software package developed by the University of Wisconsin-Madison Space Science and Engineering Center (SSEC) (see http://www.ssec.wisc.edu/mcidas/ for more information on the software). The core McIDAS software was used within image processing macros developed at ERAU for these forecast products.

4. AVIATION FORECAST PRODUCTS

The aviation weather forecast products have been designed with the General Aviation (GA) small-aircraft pilot as the intended audience. The forecast products are generated primarily from the NAM model with 3 hour increments of the forecasts for the next 3+ days. The products available on the web page http://fltwx.db.erau.edu/aviationfcst.php include clouds and visibility products, low-level turbulence products, thunderstorm and precipitation products, and general hazards products. Figure 2 shows a display of the web site.

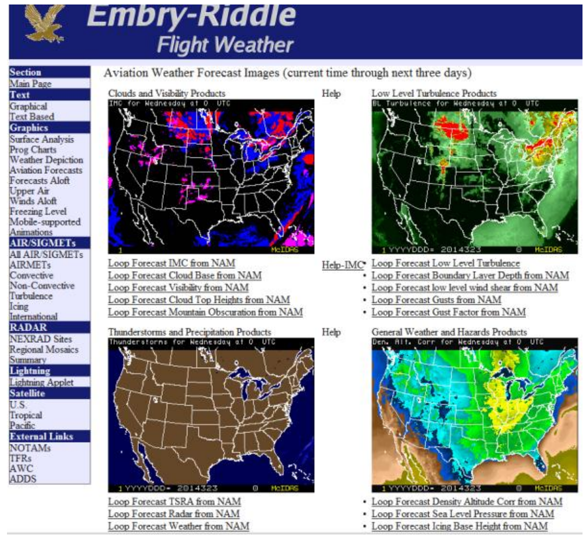

Figure 2. The web site of http://fltwx.db.erau.edu/aviationfcst.php.

Upper air forecast products available at http://fltwx.db.erau.edu/fcstsAloft.php include winds aloft in both animated streamlines and wind vector formats in addition to clouds and icing at various levels. Figure 3 shows a display of the web site.

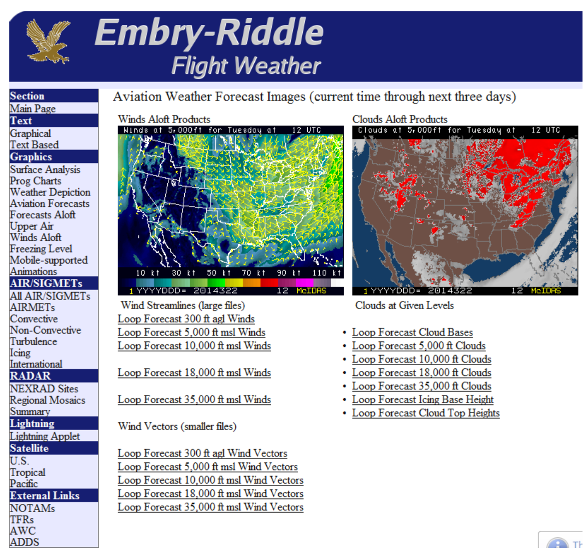

Figure 3. The web site of http://fltwx.db.erau.edu/fcstsAloft.php

The following are brief descriptions of the various products available on the web pages.

4.1 **Forecast Instrument Meteorological Conditions (IMC)**

Instrument Meteorological Conditions (IMC) refers to weather conditions with low ceilings and/or low visibility. A ceiling is defined as the height above the ground or water of the base of the lowest layer of cloud below 20,000 feet covering more than half the sky.

The Marginal Visible Flight Rules (MVFR) category (blue colors in graphic) has ceilings between 3,000 feet and 1,000 feet and/or visibilities between 3 and 5 miles inclusive. The Instrument Flight Rules (IFR) category (red colors in graphic) has ceilings less than 1,000 feet and/or visibility less than 3 miles. The Low IFR (LIFR) category (magenta colors in graphic) is a subset of the IFR with ceilings less than 500 feet and/or visibility less than 1 mile. Figure 4a shows an example of IMC conditions valid for Friday, Nov. 21, 2014 at 15Z. Figure 4a was generated by combining the visibility forecast image and the cloud base image into one product. Figure 4b shows the official AIRMET forecast for IMC issued by the AWC valid at the same time as the forecast image.

By and large the NAM forecast images in the following examples agree reasonably well with the AWC AIRMETs for the first 12 hours of the forecast period. The user is suggested to look at the web site http://aviationweather.gov/gairmet for the official AIRMETs valid for the next 12 hours.

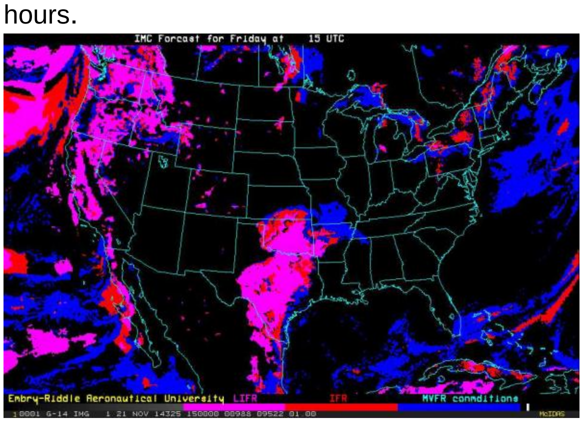

Figure 4a. *Example of IMC forecast valid for Friday, Nov. 21, 2014 at 15Z.*

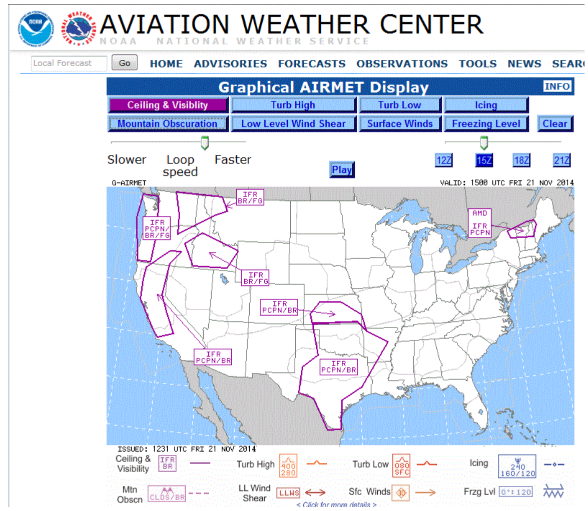

Figure 4b. *Graphical AIRMET for IMC conditions issued by the AWC valid at the same time as the forecast IMC image in figure 4a.*

4.2 Forecast Cloud Bases

Cloud Ceiling displays utilize NAM model forecasts of cloud-base and low-cloud amount to compute ceilings. Cloud-base pressure and cloud-amount calculations are generated for radiation parameterization calculations within the NAM and adopted for aviation uses. The cloud-base pressure is converted to height above ground using the hypsometric equation with the surface-pressure grid, the cloud-base pressure grid and the surface temperature grid. Since the cloud-base temperature is not available, the height-above-ground calculation may be a few percent higher than it actually is. Once the cloud-base calculation is done, only those cloud-bases with cloud amounts above 50% are shown in the display. The cloud bases which are lower than the MVFR, IFR, and LIFR criteria are colored. Figure 5 shows an example of the cloud-base forecast for the same time as figure 4.

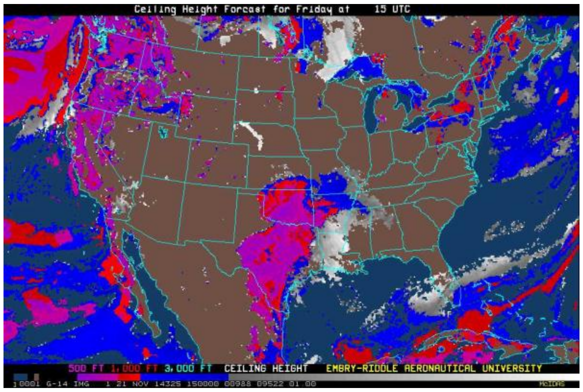

__Figure 5.__ Example of Cloud bases valid for Friday, Nov.21, 2014 at 15Z.

4.3. Forecast Visibility

Surface Visibility displays are from NAM model forecasts of visibility using the Stoelinga & Warner technique. The model visibility forecast includes reductions in visibility due to precipitation as well as fog. An example is shown in figure 6.

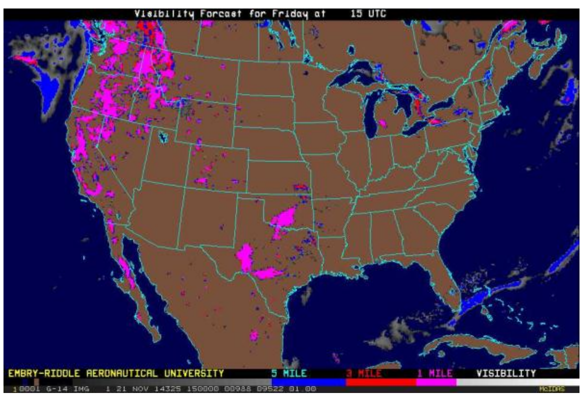

__Figure 6.__ Example of visibility forecast valid for Friday, Nov. 21, 2014 at 15Z.

4.4 Forecast Cloud-Top Heights

Cloud-top information is required for radiative transfer calculations within forecast models. The NAM model provides grids containing cloud-top pressure, cloud amount, and cloud-top temperature. To convert the cloud-top pressure into cloud top height above sea-level in feet, the hypsometric equation (Z2-Z1)=29.3*T*ln(P1/P2) is used where T is the average temperature of the layer (in degrees K), P2 is the cloud-top pressure, and P1 is the sea-level pressure. The cloud top temperature and the surface temperatures are used to compute the average temperature of the layer. For cloudy grid points, if there is any cloud within the grid, the model provides a value of the cloud top pressure. To improve the appearance of the resultant cloud top image, a random number between 0 and 1 is generated for each pixel. If the fractional cloud cover is greater than the random number, the pixel is displayed. This converts fractional cloud cover into fractional clouds. The clouds tops are displayed as colors representing thousands of feet. The color bar at the bottom of the image is used to determine the forecast cloud height. Figure 7 shows an example for the same time as the other examples

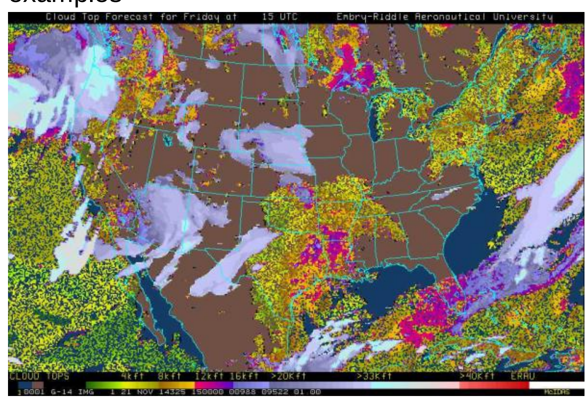

__Figure 7.__ Example of the forecast cloud heights valid for Friday, Nov. 21, 2014 at 15Z.

4.5 Forecast Mountain Obscuration

In the manual forecasts of mountain obscuration, the NWS does not provide how a mountain is defined. The definition of a mountain used in the generation of this mountain obscuration product was the surface terrain changes more than 500 feet in elevation within a 60 km (37 miles) wide running average filter. With this definition of mountains, in addition to traditional mountains such as the Appalachians etc., smaller hilly areas such as the Ozarks, show up in the forecasts. The mountain obscuration display shows a hazard if the cloud base is less than 1000 feet above the ground, the cloud cover is greater than 50%, and there are mountains using the above definition. An example of the mountain obscuration forecast is shown in figure 8a for the same time as the other example images. Figure 8b shows the AWC graphical AIRMET for mountain obscuration valid at the same time as the forecast image.

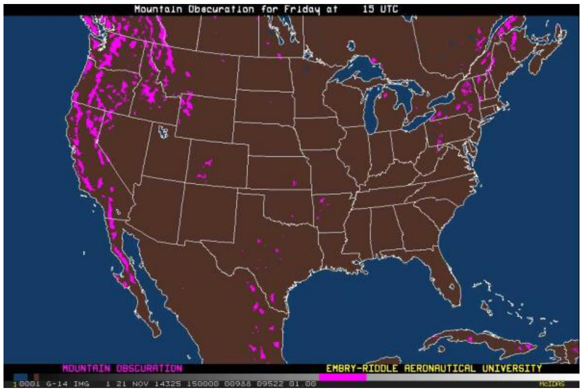

Figure 8a. *Example of mountain obscuration valid for Friday, Nov. 21, 2014 at 15Z.*

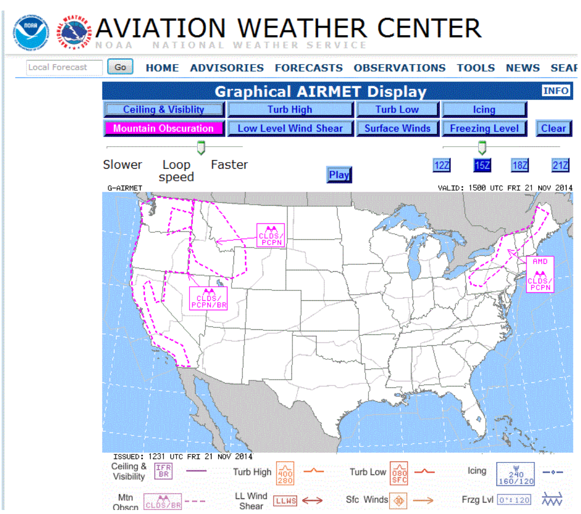

Figure 8b. *Graphical AIRMET for mountain obscuration valid at the same time as the forecast image.*

4.6 Forecast Low Level Turbulence

NCEP makes available parameterization grids on Turbulent Kinetic Energy (TKE) used in the calculation of energy loss in the boundary layer due to friction and turbulence. TKE is the amount of energy in the turbulent eddies. The NAM TKE parameterization uses the Mellor-Yamada-Janjic 2.5 level closure parameterization scheme. This provides for a well-mixed boundary layer during the daytime. The TKE parameterization provides for both mechanical and buoyant turbulence production.

Aircraft turbulence has been related to Eddy Dissipation Rate (EDR). EDR can be related to TKE by the $EDR=(TKE)^{3/2}/L$, where L is a dissipation length scale for the eddies. For studies of commercial B-737 and B-757 aircraft relationships of observed turbulence to EDR, a length scale for L of approximately 300 m was used. For boundary layer studies, a length of approximately 50 was used. For the low-level turbulence displays on this web page a length scale of 15 was used because of the response of most GA aircraft to turbulence is different than larger aircraft.

The response of an aircraft to turbulence depends upon the wing loading, airspeed, altitude, and aircraft design. The wing loading is the weight of the aircraft divided by the area of the wings. For a given updraft eddy, the larger the wing loading the harder it is to lift the aircraft. Hence aircraft with small wing loading will experience more turbulence impact than aircraft with large wing loadings for a given eddy. Commercial aircraft, such as the B-737 and B-757, have a wing loading in the range of 130-150 lbs/sq. ft. Smaller GA aircraft, such as the Cessna 172 and Beechcraft King, have wing loadings in the range of 14-34 lbs/sq. ft. Hence the turbulence experienced by a small GA aircraft could be 5-10 times that of the larger aircraft. Studies of aircraft turbulence to EDR have utilized commercial aircraft flying at altitudes of 25,000 to 40,000 ft., where the air is less dense than near the surface. For a given eddy speed, the turbulence would be greater at lower altitudes since the density is greater. The density in the lower atmosphere is 2-3 times that of the level used in the EDR studies. Combining the wing loading factor and the density factor, resulted in the value of L=15 being used.

In addition to the boundary layer calculations, the NAM uses TKE in the calculations of diffusion within the various layers of the free atmosphere. Hence TKE grids are available from the NAM at every vertical level. The available NAM data provides grids every 25 mb in the vertical. The first step in calculating the low level turbulence is to construct a boundary layer grid of TKE converted to EDR. A boundary layer EDR turbulence grid is constructed by first obtaining the surface pressure grid. Then the vertical grids are examined to extract the portion of the TKE grid which is within 25 mb of the surface pressure. The various portions of the layers of the TKE are mosaicked into a boundary-layer EDR grid. The resultant grid is converted into an image and remapped into a Lambert projection map with 6 km resolution centered at 37N 97W for a US image of the data. This image is then saved as a JPG image for web display. Data are computed for every 3 hours out through 84 hours of forecast time. Figure 9a shows an example of the computed low-level turbulence for Nov. 21, 2014 at 15Z. Figure 9b shows the official Low-Level Turbulence Graphical AIRMET issued by the AWC valid at the same time as the forecast graphic. Notice that the AIRMET in California and Arizona is for altitudes 9,000 feet to 20,000 feet. Since the forecast turbulence graphic is for the boundary layer, it does not capture this mid-level turbulence.

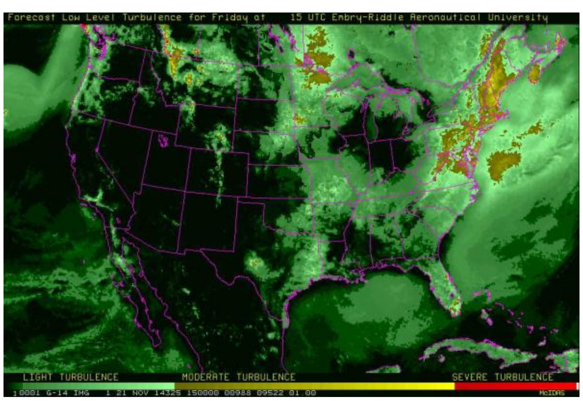

Figure 9a. *Low Level Turbulence forecast valid for Friday, Nov. 21, 2014 at 15Z.*

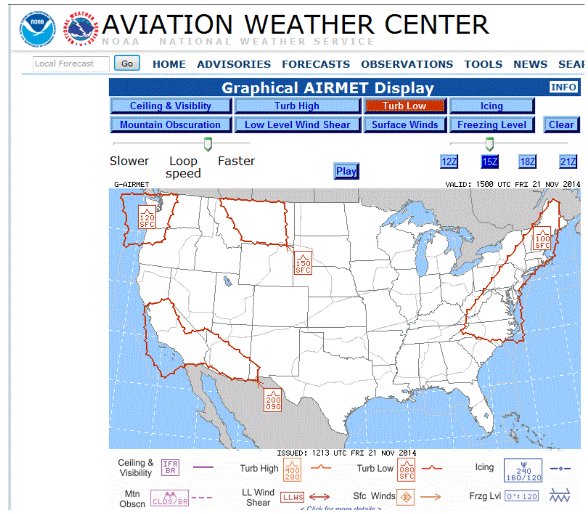

Figure 9b. *Low-Level Turbulence Graphical AIRMET issued by the AWC valid for Nov. 21, 2014 at 15Z.*

4.7 Forecast Boundary-Layer Depth

The boundary layer (also called the mixed layer) is the homogenous layer of air near the ground, which is well mixed because of low-level turbulence. Heating during the day will increase the boundary-layer depth, as will convective weather events. The boundary-layer depth is determined from the constant potential temperature vertical profile near the ground. This is determined using a critical value (0.25) of the bulk Richardson Number (see Vogelezang and Holtslag, *Boundary Layer Meteorology*, **81**, 245-269, 1996). The model boundary-layer depth has been converted from meters to feet for these displays. The boundary-layer depth can be used to determine the top of the low-level turbulence. Figure 10 shows the boundary-layer depth forecast valid for Friday, Nov. 21, 2014 at 15Z. Figure 9b showed the tops of the low-level turbulence AIRMETS. In 9b the AIRMET in the eastern US was from the surface to 10,000 feet. The forecast boundary-layer depth in figure 10 shows depths generally below 8,000 feet, except for Virginia, which has depths of 10,000 feet. Likewise, the AIRMET in Montana had a top of 15,000 feet, while the forecast boundary-layer depth showed 12-14,000 feet.

Figure 10. *Forecast boundary layer depth valid for Nov. 21, 2014 at 15Z. The top of the boundary layer generally is the top of the low level turbulence.*

4.8 Forecast Low-Level Wind Shear (LLWS)

The Low-Level Wind Shear (LLWS) is the magnitude of the vector difference (in knots) between the surface winds and the winds at 2,000 feet. The surface winds are obtained from the NAM forecast grids of the u (east-west) component of the wind and the v (north-south) component of the winds at 10 meters above the ground. The 2,000 foot winds are obtained from the Sigma (terrain following) level that is 60 to 90 millibars above the surface. In the standard atmosphere, 75 millibars above the surface pressure is approximately 2,000 feet. The low-level wind shear is computed by taking the square root of the sum of the u-component differences and the v-component differences between the levels, and converting the m/sec units to knots. Figure 11a shows an example of the forecast LLWS valid for the same time as the previous figures while figure 11b shows the AWC graphical AIRMET for LLWS valid for the same time.

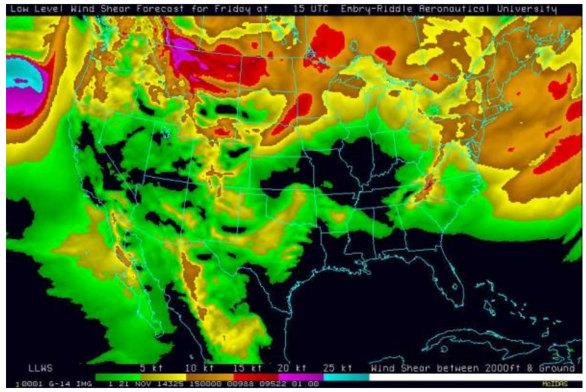

Figure 11a*.* *Forecast Low-Level Wind Shear (LLWS) valid for Nov. 21, 2014 at 15Z. The LLWS is the magnitude of the vector difference between the winds at 2,000 feet and the surface winds.*

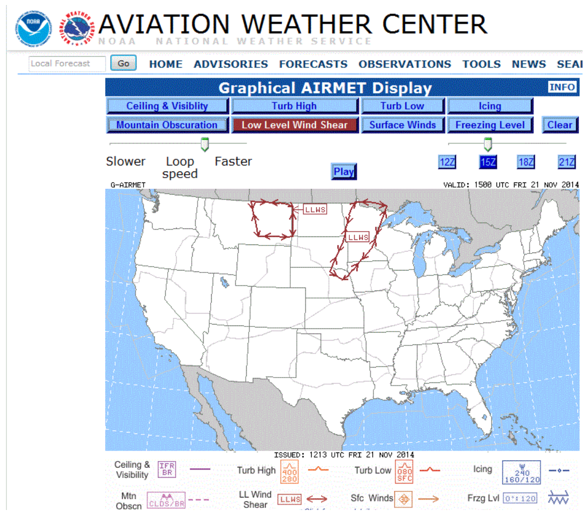

Figure 11b*.* *Graphic AIRMET for LLWS issued by the AWC valid at the same time as the above forecast LLWS.*

4.9 Forecast Wind Gusts

Surface wind gusts is a parameter computed by the NAM model and the forecast grids are made available to users. The wind gusts are determined from the winds at the top of the model boundary layer and brought down to the surface by the turbulent eddies in the boundary layer. In this display, the speed of the surface wind gusts are shown by color and the direction is shown by the arrow. The arrow length is increased for stronger winds. Figure 12a shows the forecast surface wind gusts while figure 12b shows the graphical AIRMET for surface winds greater than 30 knots.

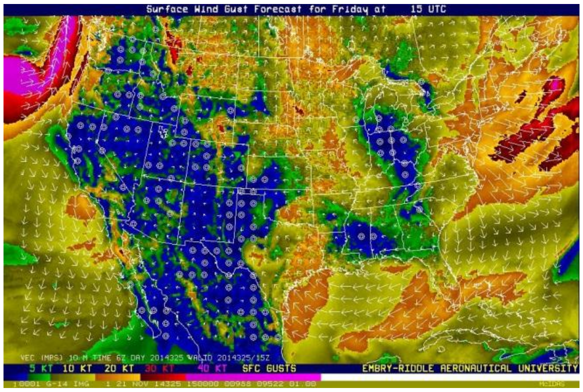

Figure 12a. *Forecast of surface wind gusts valid for Friday, Nov. 21, 2014 at 15Z.*

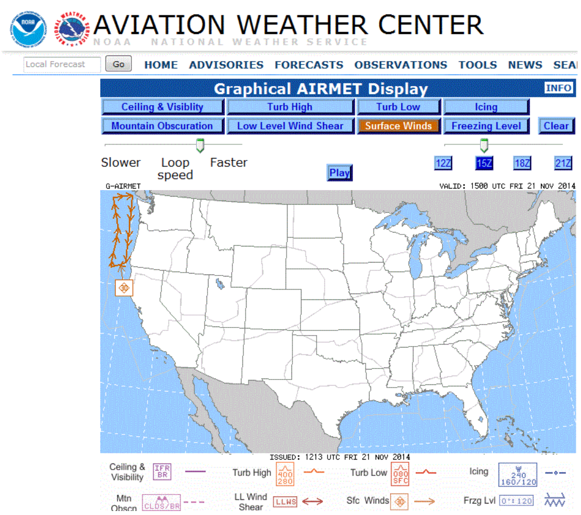

Figure 12b*.* *Graphical AIRMET for surface winds greater than 30 knots at 15Z on Nov. 21, 2014.*

In addition to the display of the magnitude and direction of the wind gusts, a display of the gust factor is available. The gust factor is the difference between the gust speed and the sustained wind speed. The gust factor can be used to estimate the ground level turbulence. The gust factor displays the ground level winds as wind barbs, and the gust's increase in wind speed above the sustained wind as colors. Figure 12.c shows an example of the gust factor for the same time as the other figures.

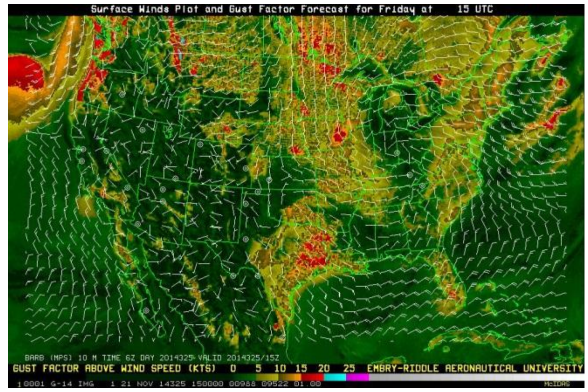

Figure 12c. *Forecast surface winds and gust factor for Friday, Nov.21, 2014 at 15Z. The gust factor is the increase in the gust speed above the sustained wind speed.*

4.10 Forecast Thunderstorms

The forecast thunderstorms utilize the NAM convective precipitation parameterization grids. The display is the 3 hour convective precipitation amounts. The colors display 0 to 0.08 inches/3hours of convective precipitation as blue shades. The yellow and orange show the range from 0.09 to 0.2 inches of precipitation/3 hours. The reds show areas with greater than 0.2 inches of precipitation/3 hours. Figure 13a shows the thunderstorm forecast valid at 15Z on Nov. 21, 2014. The convective precipitation grids are processed differently for the 06Z and 18Z model runs as compared to the 00Z and 12Z runs. For the 6Z and 18Z the NAM convective precipitation grids show the 3 hour amounts valid for each 3 hour time interval. For the 00Z and the 12Z runs, the precipitation amounts are summed for each time period through 12 hours, and then reset for the next 12 hours. While attempts were made to subtract out each 3 hourly amount, the results were not consistent between different runs of the model. Hence for the web displays of thunderstorms, only the 06Z and 18Z runs of the model are used.

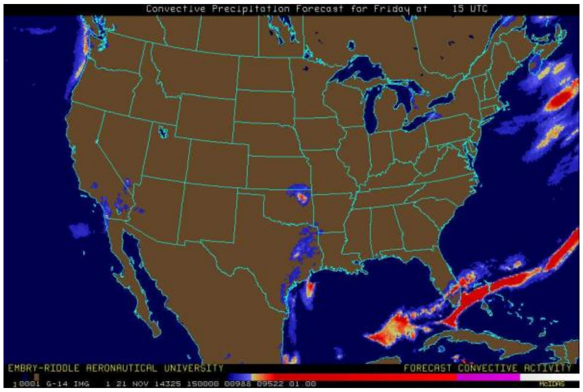

Figure 13a. *Thunderstorm forecast valid at 15Z on Nov. 21, 2014. The thunderstorms are derived from the NAM model convective precipitation parameterization.*

4.11 Forecast Radar

The NAM model grids include a forecast radar grid for each time period. The NAM takes the model precipitation valid at each forecast time period and computes an equivalent radar reflectivity factor. Since the model grid is a 12km grid, the equivalent radar reflectivity will be an average over that grid space. Since the US radar network provides 1 km resolution data, the observations can show cells with high reflectivity which have smaller space scales than the 12 km model data. Figure 14a shows the forecast radar reflectivity valid at 15Z on Nov. 21, 2014. Figure 14b shows the US radar composite valid at the same. The color scales of the two images are the same.

Figure 14a. *Forecast radar reflectivity valid at 15Z on Nov. 21, 2014 derived from NAM model precipitation valid at that time.*

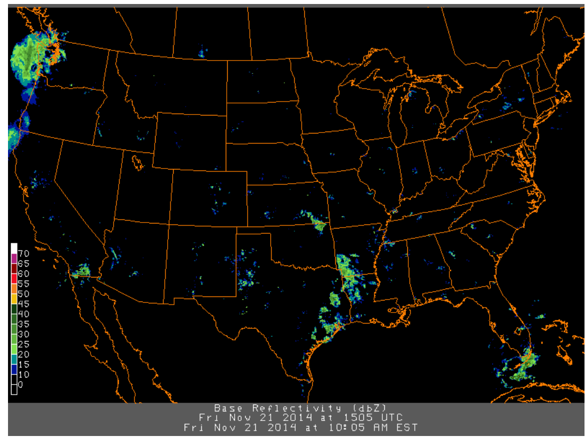

Figure 14b. *Observed radar reflectivity valid at the same time as the forecast data. The color scales are the same for the two images.*

4.12 Forecast Weather

The forecast weather display is intended as an overview product. The display shows the forecast radar reflectivity in color and has an overview of the surface winds displayed as an animated streamline. Streamlines show fluid flow by connecting wind directions into continuous lines. The McIDAS software used to draw the streamlines has a “movie” option, which divides up each line into segments of different graphic colors. The line segment lengths are proportional to the speed of the wind. For the forecast weather display, the surface (10 meter above ground) winds are used to construct the streamlines. Five graphical colors are used in the construction of the streamline line segments. Five different images are then constructed for each forecast time period. For the first image, the first graphical color is set to white, and the other 4 graphical colors are set to gray. For the second image, the second graphical color is set to white and the first graphical color is turned back to gray. The third image has the third graphical color set to white, etc. for all the other images. These five images are then saved as a single animated gif image using the Linux “convert” command. Figure 15 shows the resultant forecast weather image for Nov. 21, 2014 at 15Z. On the web displays, the streamlines move showing the wind flow. However, the text format of this report does not allow for the motion to be seen in figure 15.

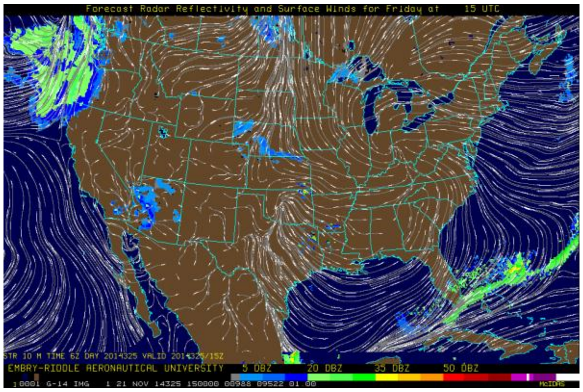

***Figure 15**. Forecast Weather for Nov. 21, 2014 at 15Z. The color underlay shows the forecast radar reflectivity while the graphical overlay shows the streamlines of the surface wind. On the web page displays, the surface streamlines are animated to show the flow of the air*.

4.13 Forecast Density-Altitude Correction

Density altitude is the altitude relative to the standard atmosphere conditions (ISA) at which the air density would be equal to the indicated air density at the place of observation. In other words, density altitude is air density given as a height above mean sea level. "Density altitude" can also be considered to be the pressure altitude of an airport runway adjusted for non-standard temperature. The display is the number of feet to be added to or subtracted from the airport altitude to equal the density altitude above sea level. Figure 16 shows the density altitude correction for Nov. 21, 2014 at 15Z. The transition between blue and brown colors is the zero correction, which is where the surface temperature corresponds to the standard atmosphere surface temperature. For colors in the blues, yellows, and greens, the density altitude is lower than the runway altitude, which means that an aircraft will need less of the runway length to take off. During the summer when the surface temperature is very hot, the brown to red colors would show the density altitude is higher than the runway, which would require a longer runway to take off.

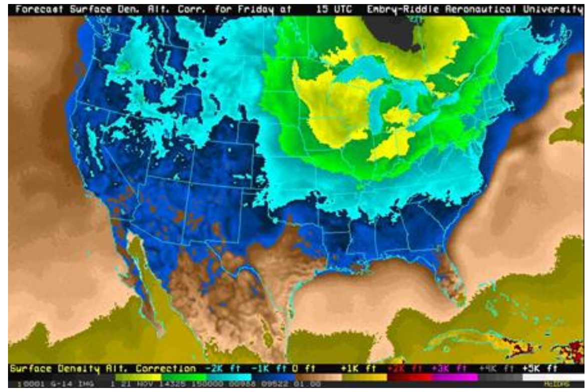

Figure 16. *Density altitude correction for Nov. 21, 2014 at 15Z. The density altitude correction is to be added or subtracted from the airport runway altitude to determine the density altitude of the runway.*

4.14 Forecast Sea-Level Pressure

The NAM model has two different sea-level pressure girds. Sea-level pressure is determined by taking the surface pressure and reducing it to sea-level via the hypsometric equation. The hypsometric equation required the average temperature of a layer between two pressures. One method of reducing the surface pressure to sea-level is to use the standard atmosphere temperature profile. The disadvantage of this is that the sea-level pressure contours closely follow mountain terrain. The other method is to determine the average subsurface temperature by horizontal interpolation from either side of the terrain. This second method of calculating sea-level pressure is what is used in the sea-level pressure display. The sea level pressure is first made into an image which is colored. The contours of sea-level pressure are than added on top of the image. This way small variations of pressure caused by surface heating or diurnal pressure changes can easily be distinguished. Figure 17 shows an example of the sea-level pressure display.

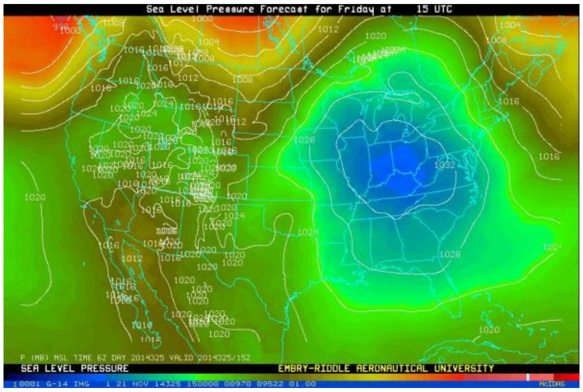

Figure 17. *Sea-Level Pressure for Nov. 21, 2014 at 15Z. The colored image is the sea-level pressure field as well as the contoured overlay.*

4.15 Forecast Icing-Base Height

Aircraft icing is caused by airplanes flying through super cooled liquid droplets which form ice on the superstructure of the aircraft. The Aviation Weather Center (AWC) issues AIRMETS and SIGMET for aircraft icing hazards. The AIRMET and SIGMET products provide an outline of the hazard as well as the base and top of the icing. The AWC also provides computerized icing guidance displays for Current Icing Potential (CIP) and Forecast Icing Potential (FIP) for odd numbered altitudes. (1,000 ft., 3,000 ft., etc.). The AWC also provides separate graphics of the freezing level. The NAM and GFS model grids do not contain enough cloud parameterization information to generate an extended range version of the FIP. The forecast icing base is computed using the available grids, with the assumption that GA aircraft will not be trying to overfly icing hazards.

The icing-base product is generated from the GFS model freezing level grid and the GFS relative humidity grid at the freezing level. Relative humidity values of 80% or higher are assumed to have clouds at the grid point. The first step of the processing is to compute a grid of the freezing level heights where the relative humidity is greater than 80%. This grid is then edited to remove any points where the NAM model cloud top grid shows no clouds. Using the freezing level height for the icing base has a problem in the winter when the surface is below freezing. Hence the icing base working grid is further edited to select the higher of the freezing level height or the cloud base height. If the cloud amount at a point is less than 50%, the icing is eliminated for that point. Figure 18a shows the forecast icing base height valid at Nov. 21, 2014 at 15Z. The colored image shows the icing base height. The contoured lines show the height of the freezing level. Figure 18b shows the Icing AIRMET valid at the same time. Figure 18c shows the FIP maximum icing potential at any level valid at the same time.

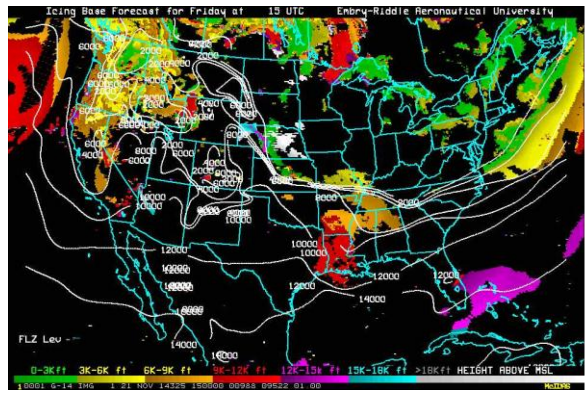

Figure 18a. *forecast icing base height valid at 15Z on Nov. 21, 2014. The colored sections are the icing base heights. The contoured lines show the freezing level in feet.*

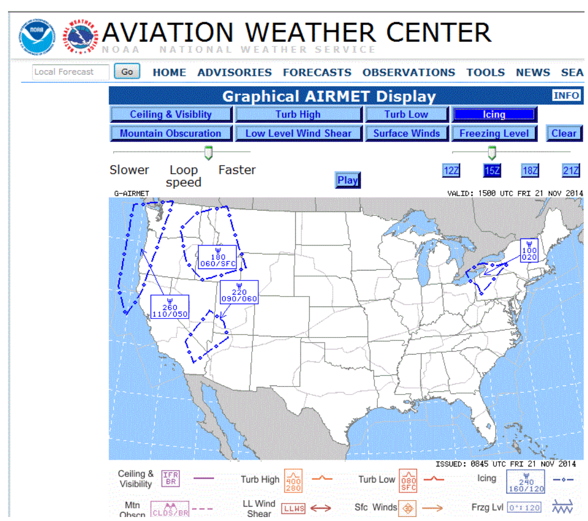

Figure 18b. *Icing AIRMETS valid for the same time as the previous image.*

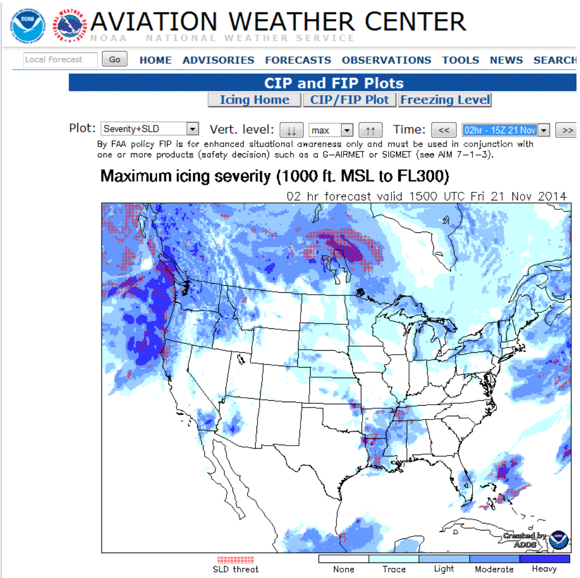

***Figure 18c**. Forecast Icing Potential (FIP) from the AWC showing the maximum icing potential for any level valid at the same time as the previous figures.*

4.16 Corrected D Value at 12,000 ft.

Pilots determine their height above sea level using an altimeter. An altimeter is a barometer calibrated to display in feet rather than pressure units using the standard atmosphere profile of pressure vs. height. The relationship of pressure to height can be calculated by the hypsometric equation. For an altimeter, there are two weather related problems with the altimeter. The first is the changing sea level pressure due to weather. The pilot can get the current sea level pressure reading (altimeter setting) from the airport of interest, and enter this value into the altimeter. While this corrects for changes in the sea level pressure, there still is the problem of the atmosphere above the ground being warmer or colder than the standard atmosphere. The D value is the difference between the true height and the pressure altitude. The corrected D value is the difference between the true height and the altimeter corrected for sea level pressure. Since all aircraft use altimeters for height determination, the D value does not make any difference for air traffic control, since all aircraft are equally in error. Where it makes a difference is for terrain avoidance. During the winter when the air temperature is colder than the standard atmosphere, the airplane will be lower than altimeter indicates. The display of corrected D value is calculated for a height of approximately 12,000 feet (about the height of the tallest mountains in Rockies). For a height of 6,000 feet, the corrected D value would be approximately half of the 12,000 foot displayed value.

The corrected D value product is generated by using the 650 mb level geopotential height (Z) field (the true height above sea level) and the height of the 650 mb level computed from the hypsometric equation using the standard atmosphere temperature profile between 650 mb and the forecast sea level pressure. Figure 19 shows the computed difference between these two heights for Nov. 21, 2014 at 15Z.

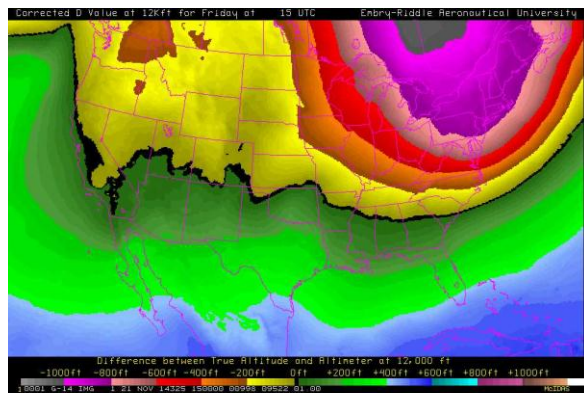

***Figure 19.** Corrected D value at 12,000 feet for Nov. 21, 2014 at 15Z. The black line between the yellow and green is the zero line where an airplane's altimeter will read the correct value. The yellows through the reds and magenta colors indicate that the airplane is actually lower than the aircraft altimeter shows. For the gray values the aircraft would be 1,000 feet lower than the altimeter reading.*

4.17 Winds Aloft

The web page http://fltwx.db.erau.edu/fcstsAloft.php provides information on winds and clouds aloft. The winds aloft displays are currently available for 300 feet AGL (80 meters above ground), 5,000 feet above sea level (850 mb level winds), 10,000 feet (700 mb level winds), 18,000 feet (500 mb level winds), and 35,000 feet (250 mb level winds). There are two different displays of the same wind information. The animated streamlines display show an image of the wind speed overlaid with an animated streamline display similar to the surface streamline display described in section 4.12. While this display is very intuitive to understand, the file size is rather large. The entire download of the forecast period of 3+ days can be as large as 30 MB. For users with high speed internet connection, this is not a problem, but for users with slower connections, the animated streamlines can be a lengthy download. The other wind display has the same wind speed background image, but has an overlay of arrows showing the direction of the wind. The length of the arrow is related to the wind speed. These files are around 4 MB for the entire forecast period. Figure 20a shows 18,000 ft. winds at 15Z on Nov. 21, 2014 with the streamline display, while 20b shows the arrow display of the same information.

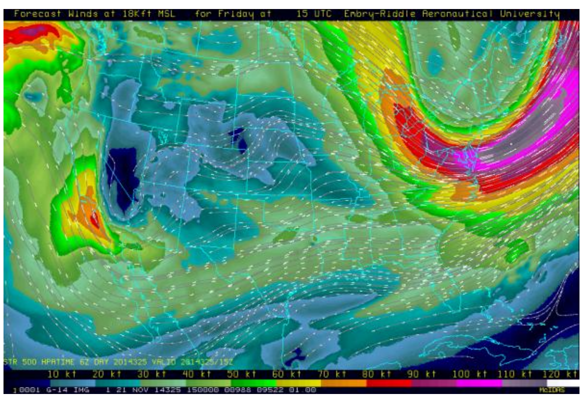

Figure 20a. *Display of wind speed and animated streamlines forecast at 18,000 feet valid for 15Z on Nov. 21, 2014.*

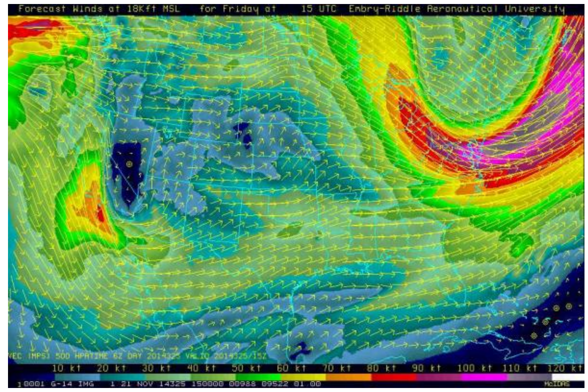

***Figure 20b**. Display of the wind speed and arrows showing wind direction valid at the same time as the previous figure.*

4.18 Clouds Aloft

The clouds aloft images at 5,000 ft., 10,000 ft., 18,000 ft., and 35,000 ft. are generated from the relative humidity fields at 850 mb, 700 mb, 500 mb, and 250 mb. If the relative humidity at that level is less than 25% at each grid point, it is eliminated at that point. The fractional cloud cover grid is used along with a random number. If the random number (between 0 and 1) is greater than the fractional cloud cover at a point, then the relative humidity value is eliminated at that point. This gives the effect of showing partial cloudiness as scattered pixels on the resultant image. The air temperature at this level is checked to determine if there is the possibility of icing. If the relative humidity is between 70% and 100% and the air temperature is between 0 and -20 degrees C, the resultant image is colored red to show icing potential in these clouds. Figure 21a shows an example of the forecast clouds at 5,000 feet valid at 15Z on Nov. 21, 2014. Figure 21b shows the visible satellite image valid for this same time.

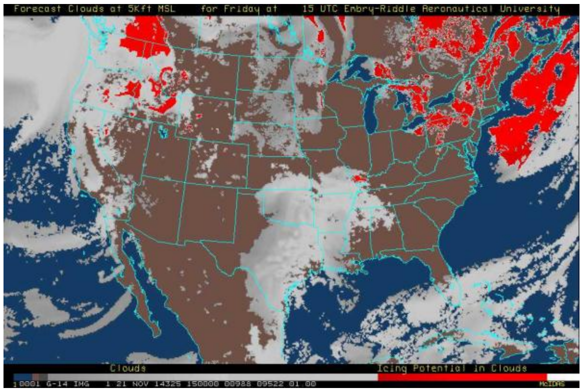

__Figure 21a__. Forecast clouds at 5,000 feet valid at 15Z on Nov. 21, 2014. The clouds with a red color have an icing potential.

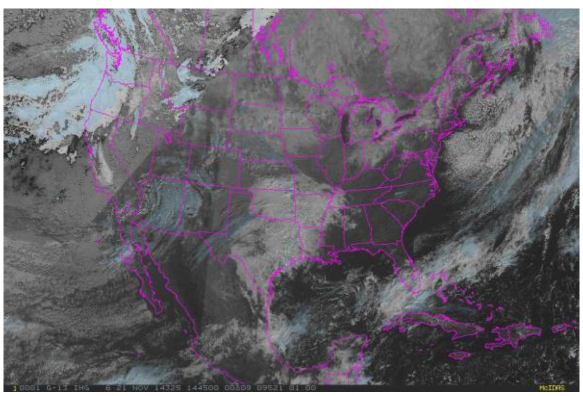

__Figure 21b.__ Visible satellite image valid for the same time as the forecast image above.

5. FUTURE DELOPMENT

The initial release of the above products has been shown to student pilots at ERAU. The initial feedback has been favorable, but there is a desire to have more control over the time period of the display loops. Future changes to the web page include adding documentation help pages for each product, and adding flexibility in time-period specifications. Having shorter loops for a specific day is being discussed as well as having the ability to display a loop of all the forecast parameters for a specific time. Future additions of forecast parameters include 3D displays of winds at multiple levels, as well as overlap of altitude calculations at 18,000 feet.