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Wiggle 3D Displays of Weather Data

Frederick R. Mosher
Embry-Riddle Aeronautical University, moshe774@erau.edu

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4A.4 **WIGGLE 3d DISPLAYS OF WEATHER DATA**

Frederick R. Mosher*
Professor-Emeritus
Embry-Riddle Aeronautical University
Daytona Beach, FL

1. A WORD IN ADVANCE

This has been a study to determine if the Wiggle 3D technique is appropriate for meteorological displays. The Wiggle 3D technique utilizes a rapidly looping set of 3D images shown on a computer screen. This study has utilized the animated GIF format of images which can be displayed in most computer browsers. However AMS requires that this paper be submitted in the PDF format, which does not supported animated GIF displays. PDF (and Word) are print format applications, so they do not support animation. Hence the reader of this extended abstract will not be able to directly view the Wiggle 3D images in this report. The reader is encouraged to utilize the web links provide to see examples of the Wiggle 3D displays.

1.1 INTRODUCTION

Weather is a time varying 3 dimensional phenomena, but the displays of weather data are inherently 2 dimensional. Since weather phenomena at one level can impact the weather at another level, it would be desirable to view weather on a 3D volume type of display. Initially weather displays were on paper and currently weather information is displayed on computer screens. The human mind can interpret 3D volume information in a number of ways. Having two eyes, the brain can detect the parallax differences between the images for the left eye being slightly different from the right eye. Objects that are closer to the observer have a greater parallax shift between the two eyes than distant objects.

* *Corresponding Author Address*: Frederick R. Mosher, Professor Emeritus Embry-Riddle Aeronautical University, 1325 Tuckaway Court, Fort Collins, CO 80525; email: mosherkf@centurylink.net or moshe774@erau.edu

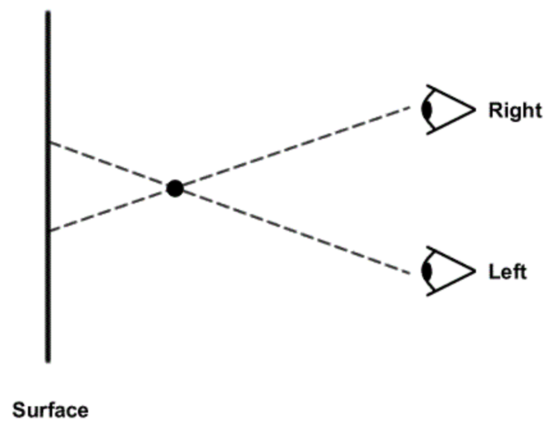

Figure 1. Objects closer to the viewer appear to have a larger parallax shift than objects further away.

Hence 3D displays can be generated by generating separate displays for each eye. The two displays can be directed to each eye using colored filters (such as anaglyph red/cyan glasses), cross polarization filters (such as RealD 3D movie glasses), or electronic glasses which switch the lens on/off in sync with the display (such as 3D TV displays). While these displays are effective, they require the user to use special glasses with dedicated 3D terminals.

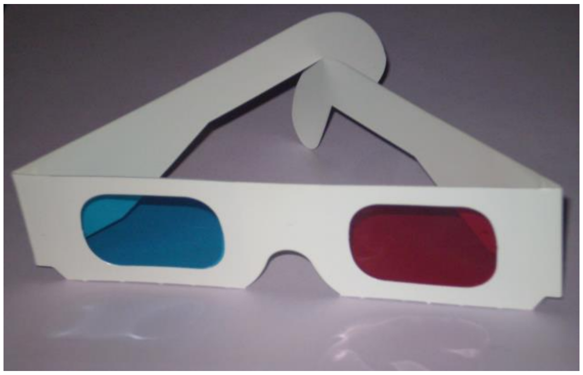

Figure 2 Anaglyph glasses used for 3D displays.

They are generally not amenable to general purpose displays such as cell phones, tablets, or ordinary computer monitors. These displays also require that the user have two equally good eyes.

2. 3D SATELLITE DISLAYS

To generate 3D images, one needs at least 2 images which contain parallax. Mosher (2012) demonstrated the generation of 3D satellite images using the infrared image to obtain cloud height and then computing 2 parallax images for the visible channel. The parallax is generated by shifting the pixels left or right an amount proportional to the computed cloud height. The amount of parallax shift is similar to that which would be generated from the real parallax between GOES-east and GOES-west. These 3D satellite images are routinely available at http://wx.erau.edu/erau_sat/ for users with anaglyph red/cyan glasses.

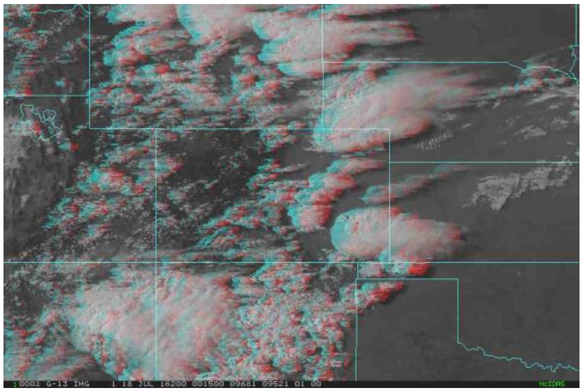

Figure 3. Anaglyph 3D image of satellite image for July 18, 2016 at 00:15Z obtained from http://wx.erau.edu/erau_sat/

3. WIGGLE 3D DISPLAYS

A second way the brain determines distance is through relative motions as the viewer changes the viewing location. Closer objects have a larger relative motion while distant objects have little relative motion. This technique is frequently used in movies where the camera is moved (panned) across the scene, allowing the viewer to discern distances. This is the principal behind "Wiggle 3D". The stereo images are rapidly looped which provides the viewer with the illusion of depth. The minimum requirement for a Wiggle 3D loop are left and right images, but intermediate images between the two provides for a more visually pleasing display. A Wikipedia article available at https://en.wikipedia.org/wiki/Wiggle_stereoscopy contains additional information on the technique. Other examples of wiggle 3D images can be obtained using Google for "wiggle 3D".

Figure 4. Wiggle 3D image obtained from http://fuzzywobble.com/images/stereo.gif. Link obtained from google.com search of "Wiggle3D" in "Images for Wiggle 3D".

The parallax generation code used in the generation of 3D satellite images can also be used to generate wiggle 3D satellite images. In the development of the wiggle displays it was determined that the parallax shift used in the anaglyph images was too large for a wiggle display. A reduced shift 1/3 of the anaglyph shift has been used for the wiggle display. This gives about 8 levels of height in the wiggle satellite display. Using the suggestion from the Wikipedia article, a third image has been added to the display. Rather than using just the two left and right parallax images, a third image of the original projection also used to reduce the jumpiness of the display. The three images are saved as a single animated gif image. For a time animation, a JavaScript program is used to loop the animated gifs. The wiggle satellite images are available at http://wx.erau.edu/erau_sat/ for the US areas of coverage for GOES-east and GOES-west.

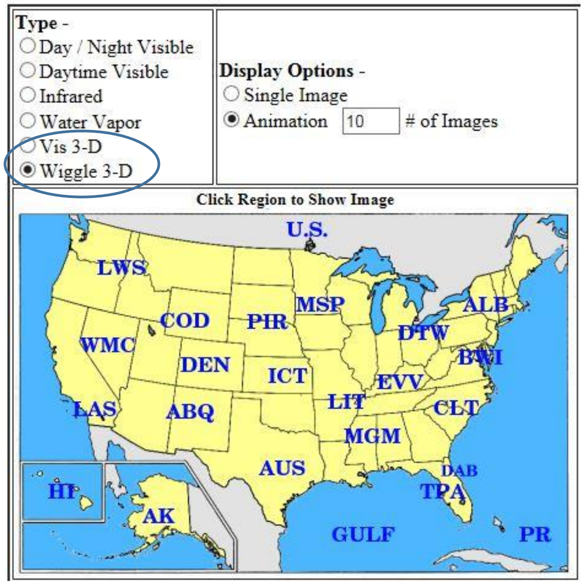

Figure 5. Selection menu for 3D satellite images available at http://wx.erau.edu/erau_sat/.

4. 3D WEATHER DISPLAYS

3D displays of weather data have a problem. How does one display the fluid's properties throughout the volume without blocking some part of the volume? One needs to see through the top layers in order to see the bottom layers. One needs some way of eliminating the obscuring data to view the data of interest.

The most common method of viewing 3D weather data is to use a volume rendering of a single iso-surface in a perspective viewpoint. 3D software packages (such as VIS5D, McIDAS-V, and IDV) allow the user to interactively move the viewing point which aids in the 3D visualization by the user. While this approach is useful in viewing 3D weather data, it has several problems. One is that only one (or two with transparency) iso-surface is rendered at a time. A normal 2D weather map will have approximately 20 iso-lines, so the information about the state of the entire fluid is limited. Another problem is that as one views the display from an angle, one cannot determine the locations of features of interest precisely. One can move to a top down view to get location, but then one has only a traditional 2D display looking down at a single contour. Since Wiggle 3D is always looking down, it potentially could be of value viewing 3D volumes of weather data.

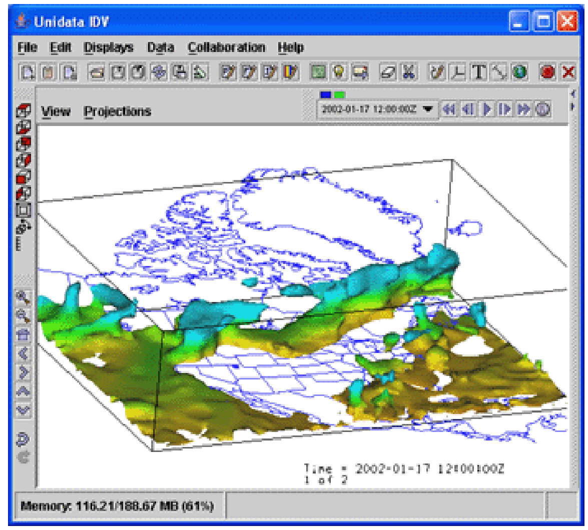

Figure 6. IDV display of 89% Relative Humidity iso-surface colored with air temperature at level of contour. IDV software is available from Unidata at http://www.unidata.ucar.edu/software/idv/

5. FAILURE OF WIGGLE 3D CONTOURS

With the success of the wiggle 3D displays of satellite data, an initial approach at displaying model data in 3D was attempted. The idea was that the upper level contours would be shifted left and right allowing the viewer to still see the lower level contours which were not shifted as much, thus allowing the viewer to see the entire volume of the weather data. Contours of model heights were displayed for five levels, with the left/right shifts being proportional to the pressure levels.

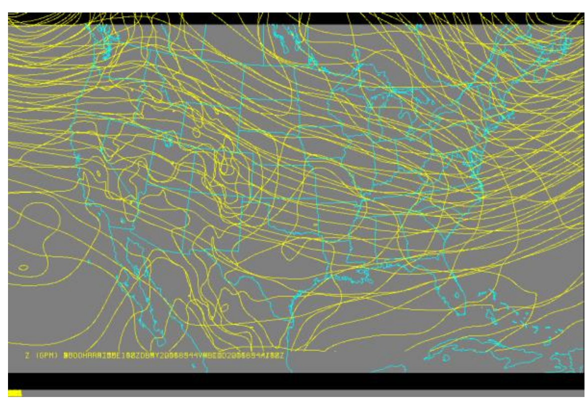

Figure 7. Contours of model height fields for 5 different levels displayed as a Wiggle 3D display. Viewer sees jumping lines rather than depth. (View PowerPoint to see wiggle effect.)

However, the resultant display just looked like lines jumping around without any sense of depth. Apparently the brain's depth perception is based on detection of identifiable objects and lines don't meet the brain's criteria for an object. Experiments were done using various line displays, and increasing the line width with height in addition to increasing the left/right shift does provide some measure of depth perception with a wiggle display. However having fat lines only worked for relatively smooth fields such as geopotential heights and temperatures. Data with a lot of variations, such as vorticity or divergence, did not display well with fat lines.

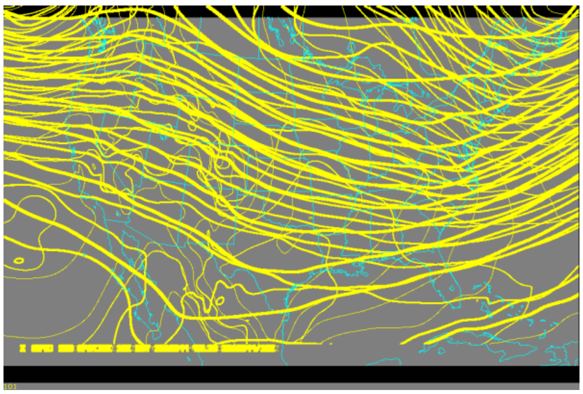

Figure 8. Wiggle 3D display of heights with upper level contours being fatter than lower level contours.

6. METEOROLOGICAL FIELDS WITH HOLES

Experiments have been done converting model grids into images (Mosher, 2015). However the images are solid, so to see the levels below the top, holes in the images are required. But holes destroy information. Initial experiments with holes first remapped the initial model image into a higher resolution projection, and then took out random holes. Having more holes in the upper levels than the lower allowed the five levels to be recombined back into a single image. While the original information from various levels could be seen with enhancements, when the combined image was shifted left and right for the wiggle display, the upper level shifting overwrote the lower level information. However having more holes to allow shifting destroyed too much information at the various level for meaningful weather displays.

Several meteorological parameters of interest (such as vertical motions) are heterogeneous with naturally occurring "holes". Holes can be generated where the field is near zero. Holes in upper level fields will allow one to see lower levels. Initial products of vertical motions appeared promising.

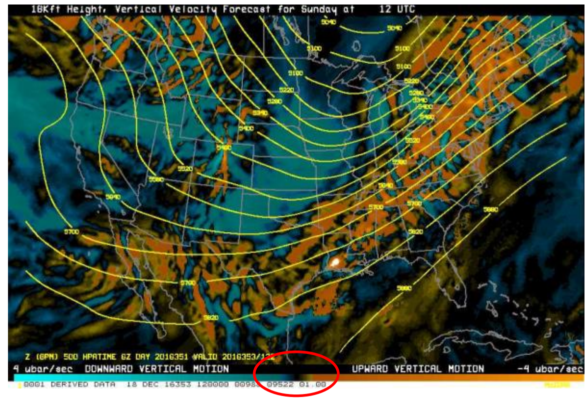

Figure 9. 500 mb vertical motions with 500 mb height contours. Values near zero can be set to zero to create holes, which enable one to see lower levels.

Six levels (200, 350, 500, 650, 800, and 975 mb) of vertical motions are generated and then combined into a single Wiggle 3D image. These images of vertical motions are routinely available at http://fltwx.db.erau.edu/aviationfcst.php. The Wiggle 3D image gives one an indication of the significant features at multiple levels. If one wants to investigate a feature in more detail, the original 2D images at the various levels are available.

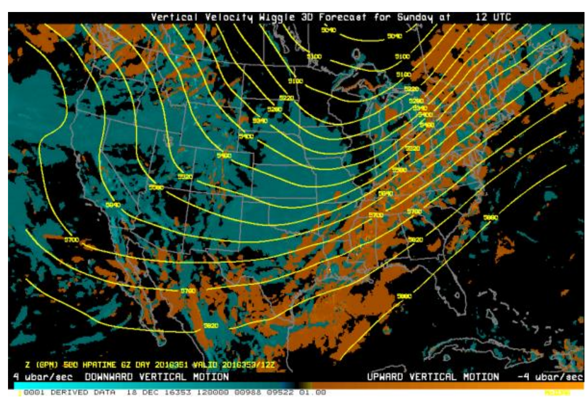

Figure 10a. Wiggle 3D image for 48 hour forecast valid at Dec. 18, 2016 12Z with 500 mb height contours. (See PowerPoint presentation to view wiggle effect).

There are several areas of interest in the Wiggle 3D image. Over Colorado is a high level mountain wave. Over New England down through the Appalachians is a broad area of mid-level QG upward motion on the east side of the trough and downward vertical motions on the west side of the trough over the mid-west. In Mississippi down through the Gulf east of Texas are areas of deep convection. Also along the Gulf coast are areas of low level convection.

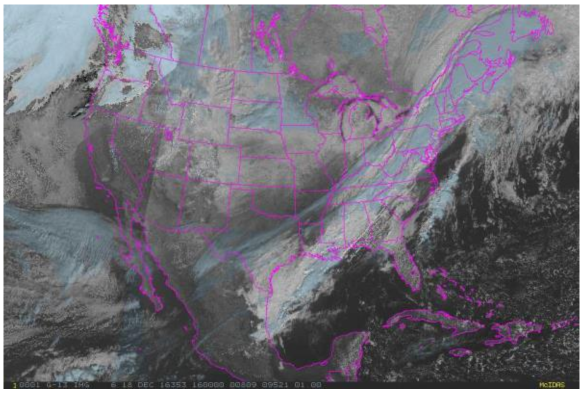

Figure 10b. Verifying day/night satellite image for Dec. 18, 2016 at 16Z. The blue shaded clouds are higher than 500 mb. The white areas in the mid-west is snow on the ground.

While the Wiggle 3D image is useful for a broad overview of the forecast vertical motions, additional information can be gathered from the 2D individual level displays.

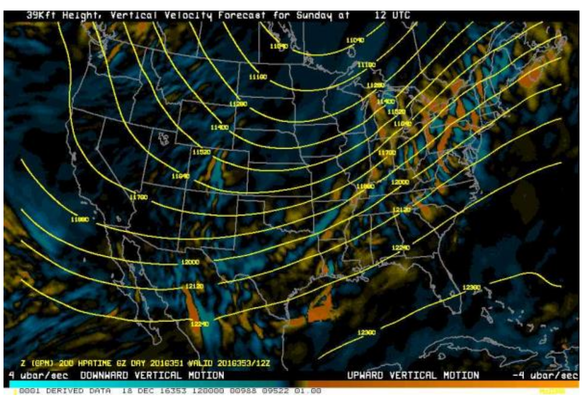

Figure 11a. 200 mb vertical motions and height contours for December 18, 2016 at 12Z.

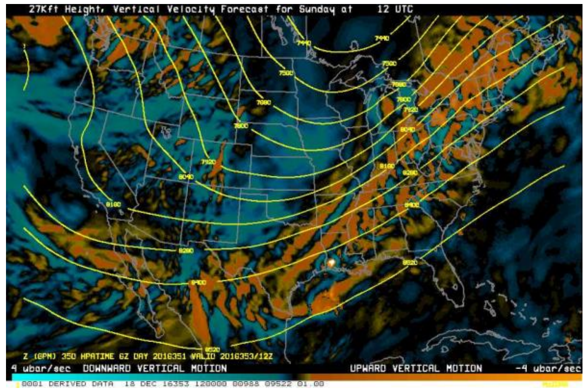

Figure 11b. 350 mb vertical motions and height contours for Dec. 18, 2016 at 12Z.

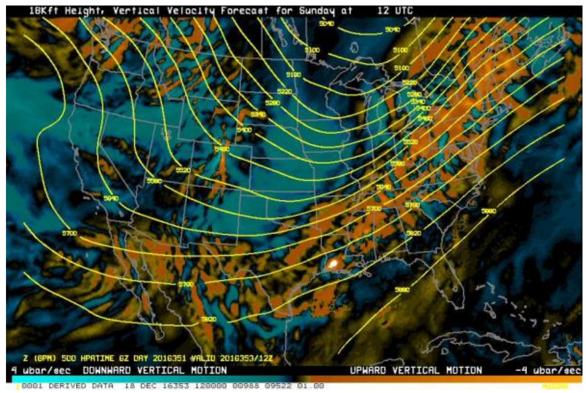

Figure 11c. 500 mb vertical motions and height contours for December 18, 2016 at 12Z.

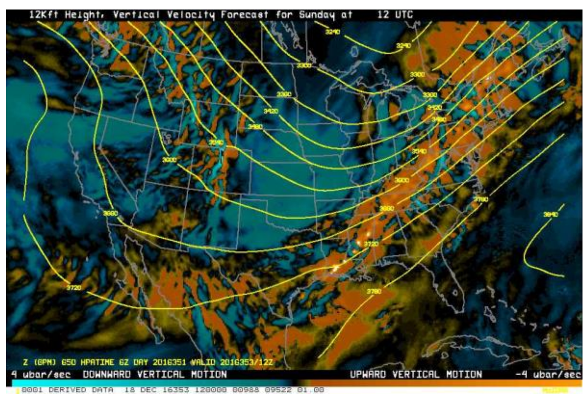

Figure 11d. 650 mb vertical motions and height contours for December 18, 2016 at 12Z.

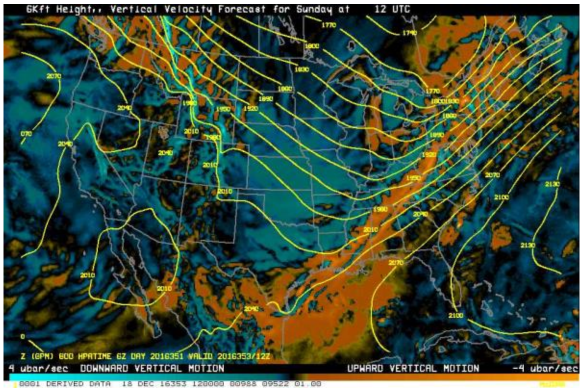

Figure 11e. 800 mb vertical motions and height contours for December 18, 2016 at 12Z.

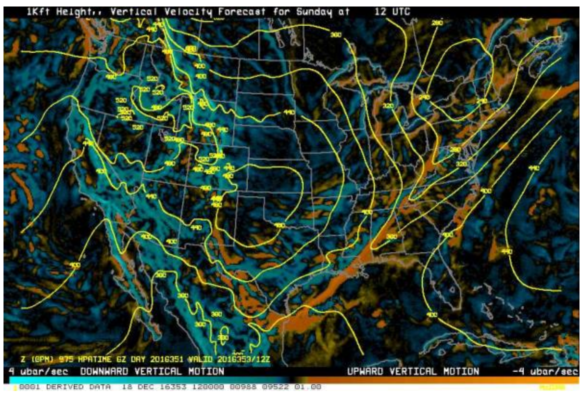

Figure 11f. 975 mb vertical motions and height contours for December 18, 2016 at 12Z.

The 2D images give additional information in addition to the Wiggle 3D image of the combination of all levels. In particular the 975 image shows the cold front stretching from New York to east of Texas. This feature is covered up in the Wiggle 3D image by the higher levels of images.

The success of the Wiggle 3D images of vertical motion has led to further experiments with other heterogeneous fields. These experiments have included temperature advection, vertical wind shear, and static stability.

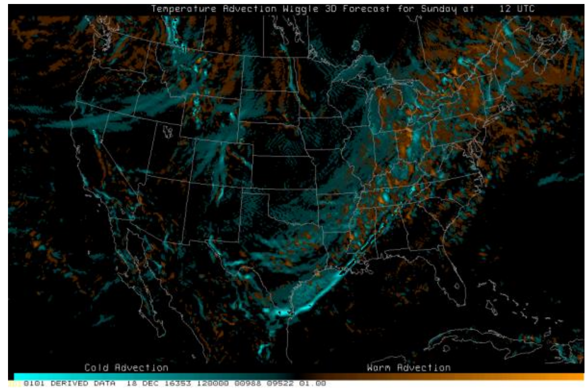

Figure 12. Experiment with Wiggle 3D image of temperature advection for Dec. 18, 2016 at 12Z. (See PowerPoint to view the wiggle effect.) Warm advection aloft leads to upward vertical motions and clouds, while cold advection aloft leads to downward vertical motions. Note the low level cold advection along the cold front.

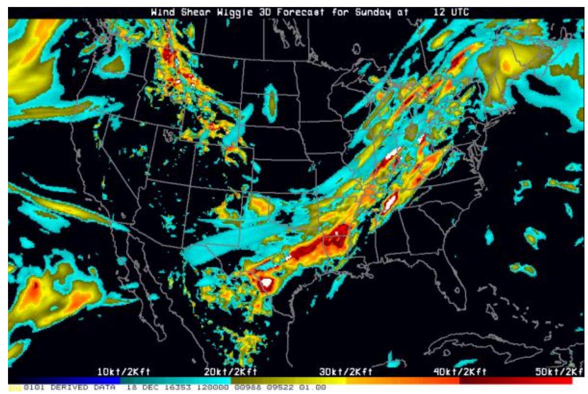

Figure 13a. Experiment with Wiggle 3D images of vertical wind shear for Dec. 18, 2016 at 12Z. (See PowerPoint to view the wiggle effect.) Wind shear is related to turbulence.

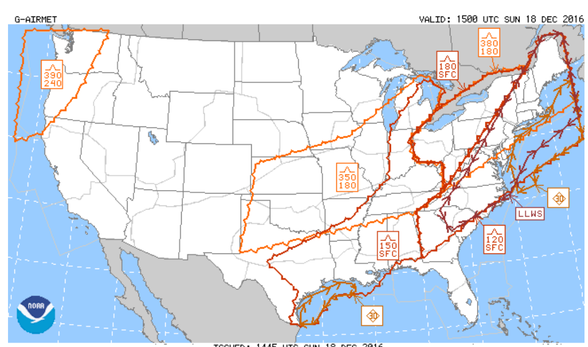

Figure 13b. AIRMETs for turbulence valid for Dec. 18, 2016 15Z. While the areas of wind shear in the eastern US are consistent with the turbulence forecasts, the areas of low level wind

shear along the mountains from Colorado to Montana are not consistent with turbulence forecasts.

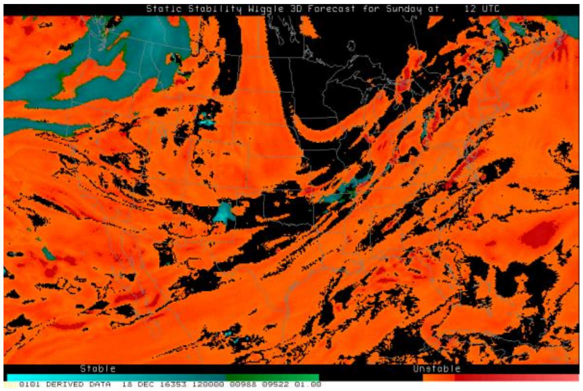

Figure 14a. Experiment with Wiggle 3D images of vertical static stability. (See PowerPoint to view the wiggle effect.) The upper levels show wide areas of unstable air, which blocks the view of lower levels.

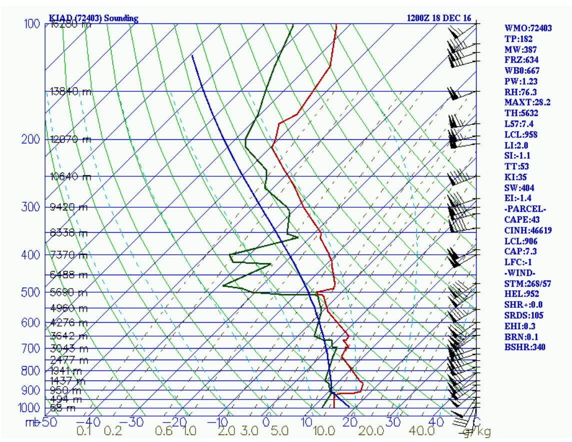

Figure 14b. Observed skewT sounding for KIAD (Washington D. C.) for Dec. 18, 2016 at 12Z. Note the sounding from 350 mb to 200 mb is almost adiabatic. Also note the thin super-adiabatic layer near 500 mb.

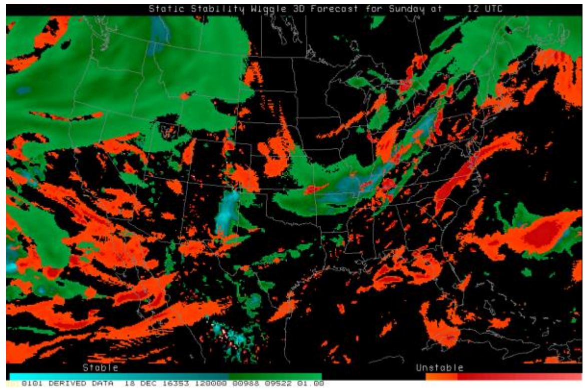

Figure 14c. Experimental Wiggle 3D image of vertical static stability with the enhancement range modified to eliminate more of the unstable image. The transition from orange to red is the adiabatic lapse rate. This allows for one to view the lower levels which show stable air behind the cold front. (See PowerPoint to view the wiggle effect.)

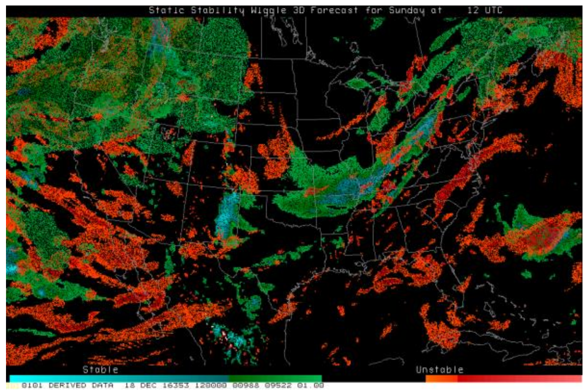

Figure 14d. Experimental Wiggle 3D image of vertical static stability with random holes (45% of area) in the upper levels (in addition to modified enhancement range of figure 14c.) to allow one to view the lower levels through the upper level. The high level stable area in the Northwest US is in the Stratosphere at 200 mb. The holes allows one to see the unstable air at mid-levels and the stable air near the ground. While the random holes help, they have not completely solved the problem of looking through upper levels. (See PowerPoint to view the wiggle effect.)

7. CONCLUSIONS

This has been a study to determine if the Wiggle 3D technique is appropriate for meteorological displays. The Wiggle 3D technique utilizes a rapidly looping set of 3D images shown on a computer screen. Conclusions of this study include:

- Wiggle 3D displays are suitable for some meteorological displays.
- No special glasses are required, so a wide range of display platforms are possible.
- Looking down, the vertical depth of display is limited (upper levels stand up a few inches above background).
- Satellite images work well with Wiggle 3D.
- Line contours at multiple levels do not work well with Wiggle 3D.
- Heterogeneous meteorological fields with naturally occurring holes, such as vertical motions, work well.
- Additional forecast Wiggle 3D displays will be added to the web site http://fltwx.db.erau.edu/aviationfcst.php in the near future.

8. REFERENCES

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