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EDUCATING AVIATORS IN VISUALIZING WEATHER

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1. INTRODUCTION

Before making a flight, aviators have the opportunity of obtaining weather forecasts from a variety of sources: Automatic Flight Service Stations (AFSS's), Direct User Access Terminals (DUAT's), The Weather Channel (TWC), and/or from local Weather Flight Service offices. One might even have the opportunity of being briefed by a Weather Forecaster at one of the NWS offices. Pilots may, under some remote circumstances, have to read the weather maps and make a forecast decision on their own initiative. By whatever method one gets the information, the ultimate decision lies with the pilot in command, whether to go, to delay, or to cancel the flight for this time. How that go/no-go decision is determined depends to a significant extent on that pilots training and understanding of weather processes. Very often these weather lessons formed part of an Aviation program where, in general, weather is taught as part of a Ground School along with the more captivating courses of Airplane Knowledge, VFR and IFR Operations, Navigation, Commercial and Multiengine Flight Operations etc. The basic understanding of the processes involved in weather (and their dynamic behaviors) are wrapped in the old slogan 'teachers teach as they were taught', and so their students may get, in many cases, a somewhat 2-dimensional view of weather processes. It is these formative perceptions that are initially drawn upon in that pilot's future weather briefings. It can be agued that if the teaching of aviation weather courses can be enhanced with relatively simple simulations and visualizations of actual weather processes in realistic situations, those pilots (aviation students) would have a much more dynamic realization of potential weather situations. Both the pilot (and indirectly the passengers) could feel a lot more confident of the outcomes being predicted and decisions would be made in a much more informed manner.

The objective of this paper is to show how relatively simple visualizations can significantly enhance, for aviators, their learning and understanding of weather processes.

2. VISUALIZING PROGRAMS - EWB

Visualization programs are readily available, even as inexpensive share-ware products. Some are freely available others are not quite so 'free'. The more costly products will have better rendition techniques and faster algorithms for doing the data manipulations and transitioning between time steps. But, with these also come added features and often a more complex user interface and learning curve. The product, *Environmental WorkBench*® (EWB) by WindLogics[1] has in our opinion, some innovative techniques for weather-data visualization that could aid in aviation education.

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3. PRESSURE SURFACES:

Pilots are introduced to the concept of pressure surfaces through diagrams such as Figures 1 and 2. In the first case, these 2-dimentional images may seem confusing, with no clear ground-level, nor altitude references available in the top image, but at least the student-pilot would realize that there is some up and down altitudes associated with pressure changes. In a more recent FAA publication (bottom image), improvements include adding the ground surface, clouds, and altitude markers. The old axiom *"From high to low, look out below"* has been used in many descriptive captions, and while truthful, it still falls short of giving any dynamic understanding to the statement, or the concept.

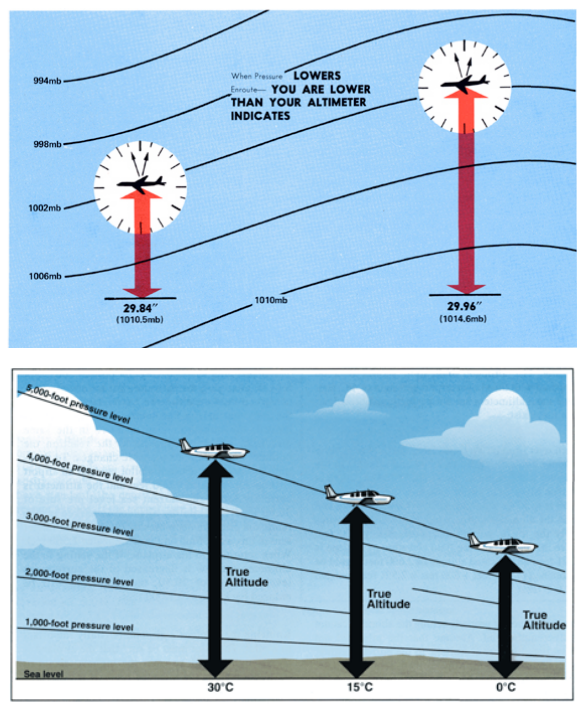


Figure 1: (Top) A familiar image taken from "Aviation Weather", showing the association of pressure surfaces in relation to height changes. (From *Aviation Weather*, Page 19). **(Bottom)** From the 2003 FAA publication *Pilot's Handbook of Aeronautical Knowledge*, Page 6-3; visual improvements have been added.

Figure 2 is a step closer to reality insofar as this diagram, taken from meteorology texts (*Meteorology Today*, by D. Ahrens and *Understanding Weather and Climate* by E. Aguado and J. Burt) gives a 3-dimensional shape to the pressure surface. With the text to support the diagram,

[1] WindLogics – (formally SSESCO), St Paul, Minnesota

the student would begin to understand that there is some textural shape to a pressure surface. The words ‘ridge’ and ‘trough’ would begin to make sense, instead of being just meteorological jargon.

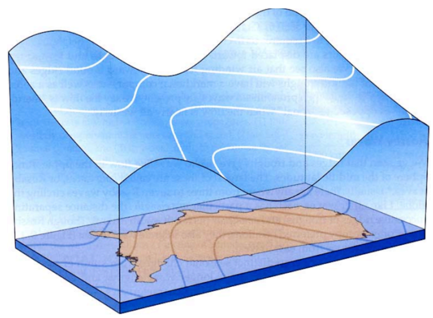
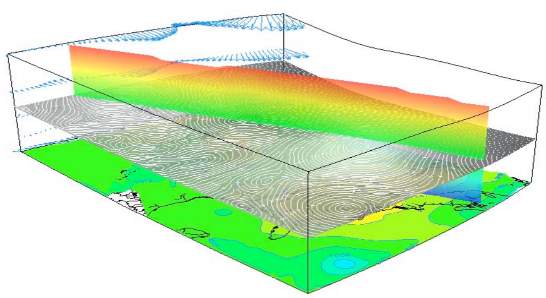


Figure 2: A 3-dimensional depiction of a pressure surface from a meteorological textbook. Interpreting the diagram without any height or pressure references leaves the image simply that. *(From Meteorology Today,* by C.D. Ahrens, Page 227*,* and *Understanding Weather and Climate* by E Aguado and J. Burt, Page 213*).*

3.1 *Visualizing Pressure Surfaces:*

The dynamic abilities of visualization programs are somewhat limited in print format, but individual frames nevertheless provide a significant step forward in understanding the relationships between the various atmospheric parameters.



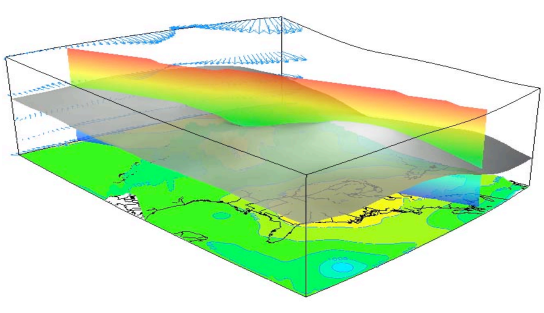
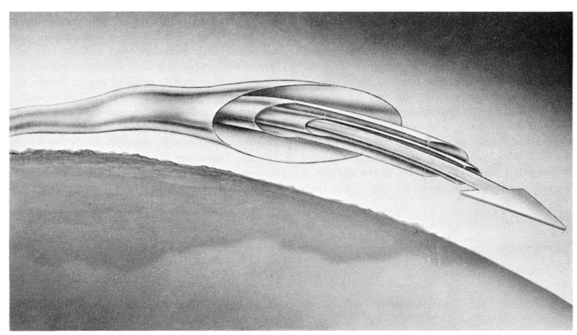


Figure 3: The 18Z image (of 9-22-04) from an animation for the period September 21-25, 2004. Surface pressure is shown (as color-filled isobars) with the 500mb surface (grayed). In the top picture the 500mb surface is flat and overlain by streamlines; In the lower image the 500mb surface has been given a height distortion depicting the actual shape of the surface at this time period. The relationship between the surface high and low-pressure systems is reflected at the 500mb level as ridges and troughs, seen against the cross-sectional slice of heights.

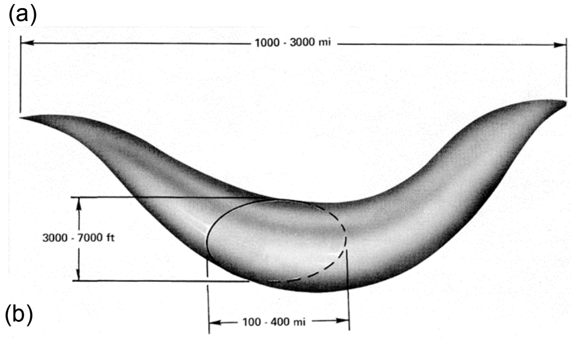
For the pilot this is particularly useful, as several important and inter-related parameters can be shown together. For example, in Figure 3, the pair of images shows the surface pressure on Sept. 22 at 18Z, with low pressures (colored in blue shades) off the Florida coast, and high pressures (shown in yellow-orange colors) viewable over the southeastern portion of the continent. In the top image the 500mb surface has been added in grayed tones on which streamlines have been superimposed. Included along the western panel of the image frame are wind arrows showing a S-N depiction of the horizontal winds at the standard pressure levels. By giving the 500mb layer a realistic distortion that unmistakably shows its contoured surface features, viewed against the vertical slice of height, has enhanced the bottom image to a meaningful depiction. No doubt is left in the mind of the aviation student that these pressure-surfaces are not constant height features. This becomes especially vivid when this is played as an animation and the weather sequence is viewed oscillating through time.

3.2 *Visualizing Upper Air Wind Flows:*

Standard aviation textbooks have treated upper level wind flows in some creative, and some non-creative ways! Figure 4 shows two diagrams from Aviation Weather where in (a) the jet stream is simply shown as a series of funneled arrows. In Figure 4(b), from the same chapter, some dimensions and textures have been added to the flow.



(a)



(b)

Figure 4: **(a)** A depiction of the jet stream from *Aviation Weather*, as part of the discussion of upper air wind flows. **(b)** Comes from the same chapter, with some numerical values of size added. (From *Aviation Weather*, Page 137)

Meteorology texts have generally handled upper-level wind flows in diagrammatic form (Figure 5) with 3-D simulations usually given on an accompanying CD. Some textbooks show polar hemispheric maps that show streamline flows that further improve upon a student's perception of the phenomena.

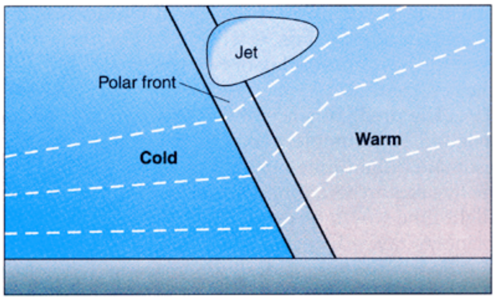
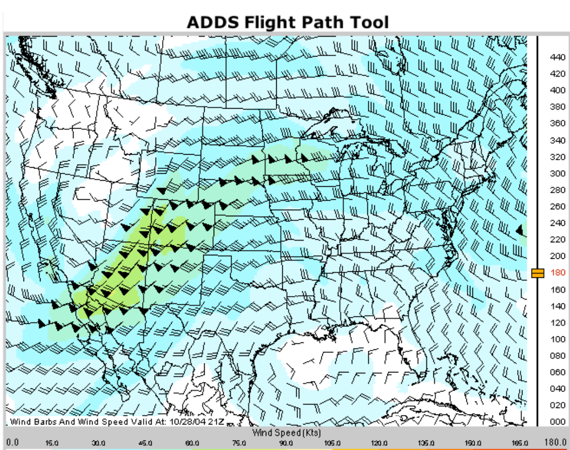
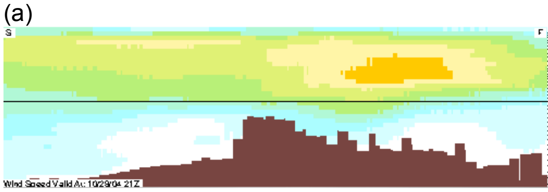


Figure 5: A depiction of the jet stream from Understanding Weather and Climate. The text amplifies this diagrammatic explanation with an accompanying CD. (From *Understanding Weather and Climate* by E Aguado and J. Burt, Page 212)

The National Weather Service has recently introduced an innovative and impressive service showing the upper air winds in real time from model forecast data. Their Aviation Weather site, (http://adds.aviationweather.noaa.gov/) has a Flight Path Tool where one can interactively choose a flight altitude (say 18,000ft) and after a short wait, the model winds for that height are graphically shown on the chart (Figure 6a).



(a)



(b)

Figure 6: (a) A depiction of the NWS ADDS Flight Path Tool of winds at 18,000ft for October 27, 2004 (19Z). **(b)** By scribing a flight path from MSP to SAN a graphical representation of the vertical wind profile is obtained. All of these are interactive services obtained directly on the URL.

By scribing a flight path across the map and double-clicking, a cross-sectional isotach chart is drawn showing the wind profile for that hour (Figure 6b). This is a most useful and stimulating service for flight planning and a good tool for understanding immediate weather patterns.

For classroom education, EWB has some eye-catching advantages for the student aviator by being able to show once again the interactions of several parameters in wind flow simulations.

No longer are jet streams envisaged as thin bands of winds associated with semi-continuous waves of the polar frontal system. But, by using real data, the vertical and horizontal dynamics of these flow systems can be shown by choosing to create imbedded isotach-surfaces, which can be shown in conjunction with any pressure-level streamline flow, or, any other parameter of choosing. What becomes particularly detectable for the aviator are the subtle textures of the flow system, the dynamic vertical extent, and the inter-relation that these wind systems have with surface pressures and temperatures. The picture of understanding is vividly enhanced.

Figure 7 shows an EWB depiction of the jet stream on 10-2-04 at 14Z. What becomes clear is its discontinuous nature and the irregularity of the westerly wave form. Actual wind speeds have been colorized with the highest jet streak shaded orange, as an iso-surface of 90 kts. This is seen against a backdrop of surface pressures that can be used to enforce the connection between the surface and the upper-air wind-flow systems.

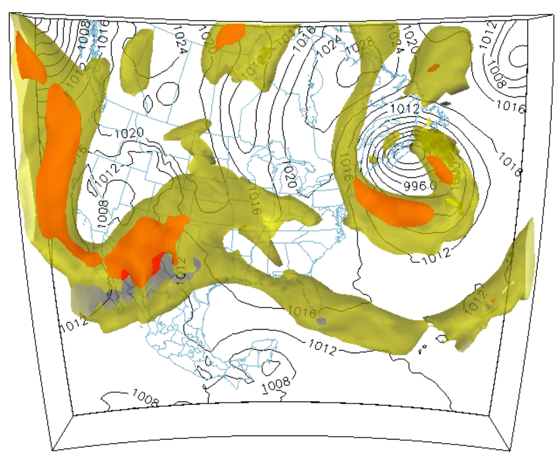


Figure 7: An image from EWB depicting the jet stream (yellow) and jet streaks (orange). Designed to show the dynamic nature of the jet stream and upper air winds.

Figure 8a shows a side view of this time-slice that clarifies the vertical extent of this flow system. What now becomes relevant is the vertical variability of the jet-stream winds and, at this particular time-slice (18:30Z), a downburst feature on the leading edge of the wind-bulge (framed in red) appears in the flow pattern. It occurs in the wind flow associated with the occluding low-pressure system over New England. Wind flow patterns are further identified by the two vertical cross-sections showing wind arrows protruding from the colored isotach surfaces. These emphasize that wind shear occurs both in the vertical and horizontal planes, often very abruptly both in time and space. The dynamics of these flow systems are more powerfully visualized when played through an animation sequence, and for the aviation student, it becomes even more realistic and meaningful if this is envisaged as happening during an imagined flight travel. EWB allows the user to tilt, turn and animate through a weather sequence, and also for one to zoom in on features. This is demonstrated in Figure 8b where the downburst feature is enlarged to illustrate the dynamic behavior of upper level wind-flow systems and to show some of the finer textures of wind shearing.

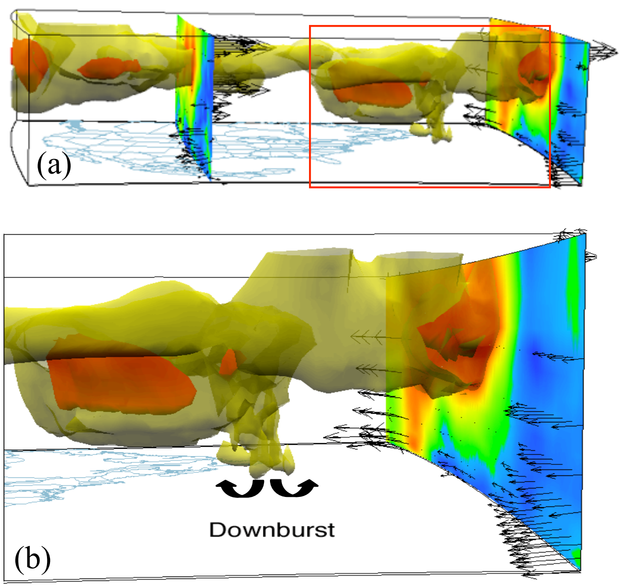


Figure 8: Images from an EWB simulation for a weather event occurring Oct. 2-5, 2004. **(a)** Shows a side view of the upper level wind flow with iso-srufaces of the wind speeds shaded to depict 'jets' of flow. The two slices portray colored isotach surfaces with horizontal wind arrows protruding at the significant pressure levels. A downburst feature appears on the leading edge of the bulge associated with the occluding low over New England. **(b)** Shows an enlarged view of the downburst demonstrating, to the aviation student, the dynamic extent of vertical wind behavior.

4.0 CONCLUSIONS

Visualization software can greatly enhance the way aviation students understand and conceptualize weather. The fact that their profession forces them to live *in,* and *fly by,* '*the weather'*, further compels the teaching of aviation weather to be more than 2-dimensional. What and how students learn is crucial, because **this** is what is recalled at times when immediate explanations are demanded. Relatively simple 3-dimensional simulations, using real data examples that are interactively viewable from all angles, can provide long-lasting images in a student's understanding. It is when their level of formative understanding is enhanced, that depth has been added to their knowledge, and explanations can be based on believable scenarios. This makes for a confident and a safer pilot.

5.0 REFERENCES:

Ahrens, C. Donald; *Meteorology Today: An Introduction to Weather and Climate*, (7th Edition), Thomson & Brooks/Cole, 2003, ISBN 0-534-39771-9

Aguado, Edward and James E. Burt: *Understanding Weather and Climate*, (2nd Edition), Prentice Hall, 2001, ISBN 0-13-027394-5

Department of Transportation, FAA: *Aviation Weather: For Pilots and Flight Operations Personal*, Revised 1975, Washington D.C. Stock Number 050-007-00283

Department of Transportation, FAA: *Pilot's Handbook of Aeronautical Knowledge*, 2003, Washington D.C. Stock Number 050-007-00283