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Testing Web-Based Preflight Weather Self-Briefing for General Aviation Pilots

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16. Abstract

The Internet affords an increasingly capable, economical, and popular vehicle for preflight weather self-briefing. This research constitutes the first known experimental investigation of how modern Web-based weather products are actually being used by general aviation (GA) pilots.

A data-gathering emulation of the National Weather Service Web site *http://aviationweather.gov* was written for use on a personal computer. Eighteen Web pages were created to display weather information, each page emulating a similar category of product shown by *aviationweather.gov*. This formed the primary weather briefing site for two similar, challenging weather scenarios subsequently flown by 50 GA pilots in simulated cross-country VFR flight.

Two dependent variables were measured—*page views* (which pages each pilot viewed) and *pageview duration* (how long each page was viewed). *Total briefing time* was then calculated for each pilot by summing pageview durations. A groupwise *"dwell" index* was also derived for each Web page by multiplying the group's page views times its median pageview durations.

A number of specific findings emerged from the data analysis. First, given a specific flight mission, we found that, as a group, GA pilots appeared significantly consistent over time in the *kinds of information* they sought out. However, the *amount of time* they spent examining that information seemed to vary over time, even given similar flight situations.

Second, pilots seem to have *favorite information sources* (e.g., graphical prog charts, TAFs, NEXRAD, and satellite cloud images). We could expect those favorites to shift slightly, depending on the flight mission.

Third, Web page design is potentially important. For example, pages not accessible from the top-level menu may be ignored or overlooked.

These findings are important to weather information providers because the ability to display certain types of information—and certain ways of displaying it—are sure to give the knowledgeable provider an advantage over competitors. The key is to have highly informative pages that still remain easy to understand.

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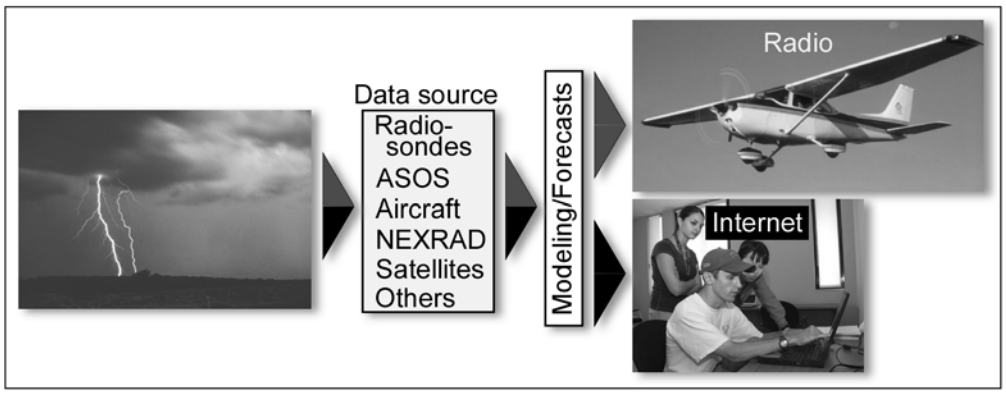


Figure 1. The basic data path of weather information (ASOS and NEXRAD are explained below).

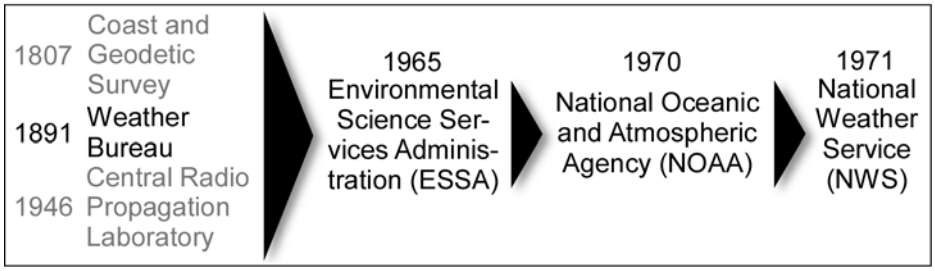


Figure 2. Main predecessors of today's U.S. National Weather Service.

INTRODUCTION

Purpose of This Research

During 2008, FAA Civil Aerospace Medical Institute (CAMI) researchers were tasked by the FAA Flight Standards division (AFS-810) to explore several issues in general aviation (GA), including *how modern Internet-based weather products are used during preflight briefing* (Knecht, Ball, & 2010a, b). This began a human factors study of what promises to be the future of GA preflight weather briefing—self-briefing by pilots using Internet-based tools. The creation of the software used to test that self-briefing, the methodology, and the results of statistical tests form the subject of the current report.

The idea that Web-based self-briefing will become a major element of flight preparation requires a convincing argument. We begin by observing that the necessary informational infrastructure is here already and can be expected to expand and improve. Let us briefly review the basics of that infrastructure.

The Basic Data Path

Weather information follows a basic data path from Nature to end-user. Figure 1 shows that path, starting with adverse weather and ending with a pilot, either on the ground or airborne. The report you are now reading will focus on the "Internet pathway" for preflight briefing (as opposed to the in-flight pathway for updates).

A Brief History of Preflight Weather Briefing

In the early days of flight, "weather briefing" consisted of stepping outside to see what was going on, as best one could. The world has changed considerably since then. There is now extensive governmental infrastructure dedicated to gathering, processing, and making public a wide variety of meteorological information.

In the U.S., this process formally began in 1807 with President Thomas Jefferson's "Survey of the Coast" project. Figure 2 shows a highly abbreviated history of U.S. weather agencies (condensed from Shea, 2010).

Currently, the National Oceanic and Atmospheric Agency (NOAA) serves as the parent organization of the

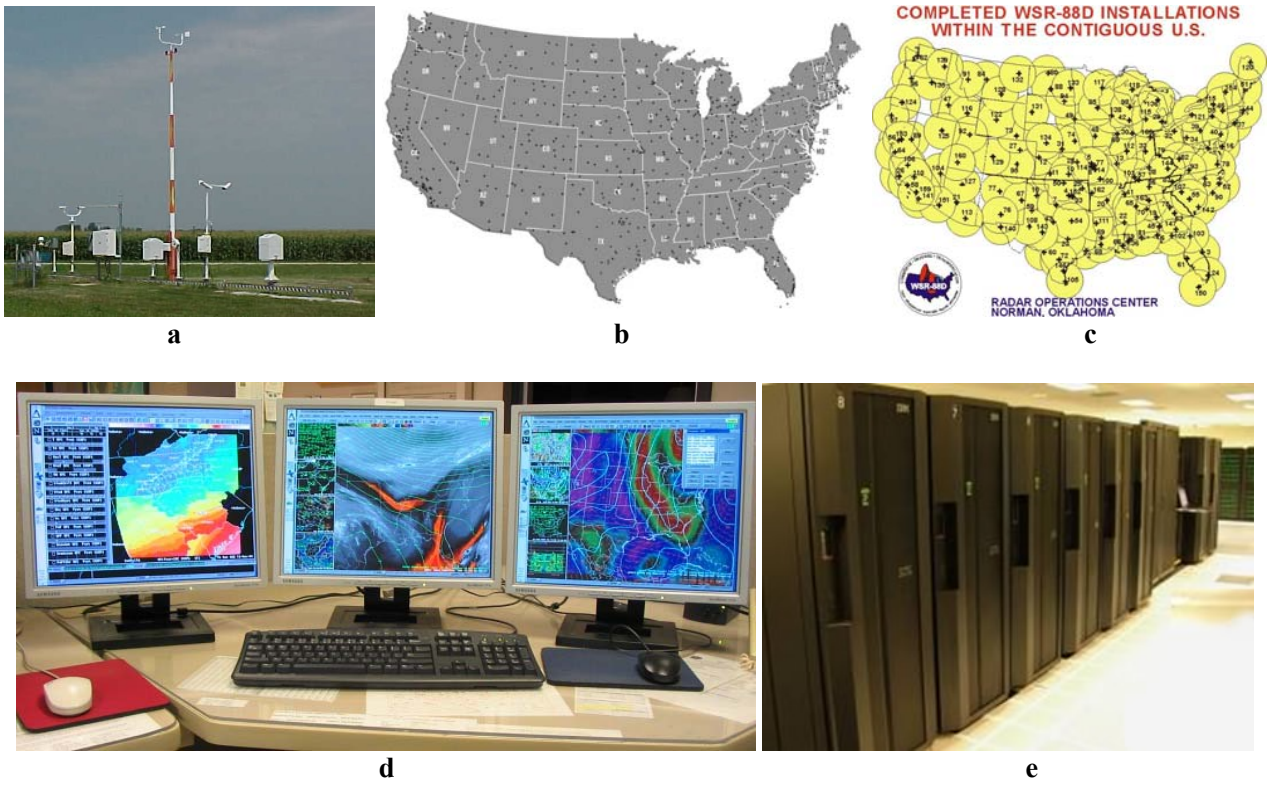


Figure 3. a) an ASOS station; b) U.S. ASOS coverage; c) NEXRAD coverage; d) AWIPS workstation; e) NOAA IBM Power6 P575 supercomputer. Photo credits: a-c, e (NOAA), d is public domain per author, Jonathan Lamb.

National Weather Service (NWS), which provides U.S. aviation most of its weather information.

Today, NOAA and the NWS provide nearly all the raw weather data used in U.S. aviation. We typically see these raw data repackaged as mid-level weather information *products*, for example:

- AIRMET .....Area Meteorological Forecast
- FA.....Aviation area 18-h forecast
- FD .....Winds and temperatures aloft
- METAR.....Meteorological Aviation Report
- PIREPS.....Pilot reports[1]
- SIGMET .....Significant Meteorological Forecast
- TAF .....Terminal Aerodrome Forecast

These products are then reorganized and bundled by weather information *providers* into more user-friendly systems such as the Direct User Access Terminal Service (DUATS), commercial products by companies such as XM and WSI, and—of course—the Automated Flight Service Station (AFSS).

One of the premier weather providers emerging today is NWS' *www.aviationweather.gov*.[2] This service is free to the public and is highly informative and useful. For these reasons, emulating and testing *aviationweather.gov* became the focus of the current study.

The goal of all these information providers is to convert what would otherwise be hopelessly complex masses of raw data into simpler, more meaningful graphical or textual forms that help pilots, airline dispatchers, and air traffic controllers make logical, timely, safe decisions about the movement of aircraft.

NWS' Primary Technological Systems

Beginning in the 1980s, the NWS itself was modernized with the following critical technological infrastructure (Figure 3 illustrates):

1. ASOS: (Figs. 3a, b). Automated Surface Observation Systems are a network of more than 800 modular, automated ground-based sensor units collecting wind speeds/directions, temperature, barometric pressure, humidity, precipitation, and visibility data. These were deployed in the early 1980s.
2. NEXRAD: (Fig. 3c). The **Nex**t-Generation Weather **Rad**ar system is a ground-based network of 159 Doppler weather radars. Doppler radar is quite sensitive to high-frequency radar phase shifts induced by *horizontal movement* of "hydro-meteors" (e.g., rain drops or insects) driven by wind). This enables NEXRAD to detect, not only precipitation and speed\direction of moving storm systems, but also wind flow fields,

[1] PIREPS are currently collected and distributed by local Flight Service Stations, rather than by NWS.

[2] An alternate name for this service is the Aviation Digital Data Service (ADDS).

turbulence, wind shear, and micro-bursts. These radars were first deployed in 1990.

3. AWIPS: (Fig. 3d). The Advanced Weather Interactive Processing System processes data from satellites, surface radars, and surface observation stations. It integrates and displays data in ways useful to modelers and forecasters (e.g., superimposing barometric pressure isobars from surface observation stations on top of known storm cells provided by NEXRAD). AWIPS was deployed in the late 1990s,
4. Supercomputing: (Fig. 3e). National Oceanic and Atmospheric Administration (NOAA) supercomputers use multiple central processing units (CPUs), operating simultaneously on vast amounts of sensor data, to rapidly process computationally complex forecasts and weather models (NOAA, 2009). The latest NOAA machines now utilize up to 5000 CPUs and provide sustained computing speeds up to 70 teraflops.[3]

The net result of modernization has been to afford faster, more extensive, more reliable, and more *publically accessible* weather information than ever before. Most of this accessibility has been due to the rise of the Internet.

The Rise of the Internet

What we today know as the Internet began in the mid-1960s with the experimental ARPANET project of what is now the U.S. Defense Advanced Research Projects Agency (DARPA, Waldrop, 2010). Expanded in the mid-1980s by U.S. National Science Foundation (NSF) funding, commercialization of the Internet began in the late 1980s. Exponential growth quickly followed. As of February 2010, estimated U.S. Internet usage stands at over 234 million individuals (Nielsenwire, 2010)—representing about 75% of the national population (U.S. Census Bureau, 2009).

The point of this history is to demonstrate that the Internet is simultaneously *widely available* and *popular*—two vital preconditions for the spread of an information technology such as preflight weather self-briefing. In fact, availability and popularity are now so extensive that the significance of the "Internet Revolution" is widely likened to Gutenberg's development of the printing press.

Central to the Internet's potential growth is a third precondition involving functionality, namely the *rapid, inexpensive transmission of large amounts of information*. This depends on average transmission speed.

[3] *Teraflops* is a measure of computer speed, representing "one trillion floating-point operations per second." A floating-point number is an integer followed by a decimal (e.g., 34.997), typically represented in hardware by a 64-bit number (footnote 4 describes bits). A flop itself is an arithmetic operation, for instance, addition or multiplication.

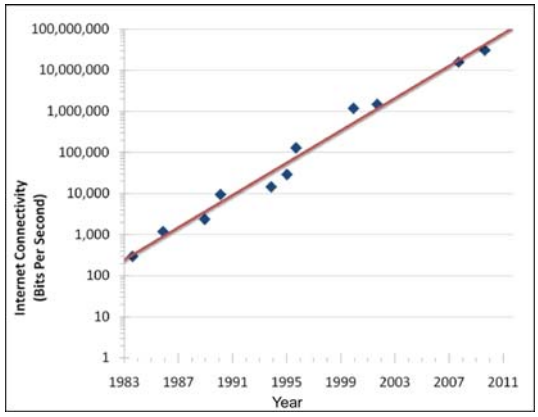


Figure 4. Internet transmission rate for Nielsen's computer (used by permission of author). Note that the x-axis is linear, the y-axis, base-10 logarithmic. The linear regression line therefore represents exponential growth.

Average transmission speed (or *bandwidth*) itself depends upon two essential technologies: a) computers to generate and receive information, and b) a network of cables, routers, transmission lines or towers, and satellites to rapidly move that information from origin to destination. Various formal principles describe how computational speed and bit[4] transfer rates across the Internet are influenced, including:

1 *Moore's Law* states that high-end *computers* will theoretically double in speed about every 18 months (Moore, 1965).[5]
2 *Nielsen's Law* states that high-end *users'* Internet *connection speeds* will theoretically double about every 21 months (Nielsen, 2010). Figure 4 illustrates Nielsen's[6] own personal Internet connection speeds increasing exponentially over time.
3 *Bloat* describes an opposing trend—that *computer code* will get bigger, less efficient, and significantly slower with time (Kennedy, 2008).
4 *Bulk-up*[7] describes a second opposing trend—that *computer applications* will become increasingly capable, at the expense of becoming more complex and computationally intensive.

[4] A *bit* is the smallest piece of transmittable information, representing either a 0 or 1 in base-2 (binary) numbers. In actual digital transmission, a 0 is typically sent as a low-strength energy pulse, a 1 as a significantly higher-strength pulse.

[5] The original idea stated that the number of *transistors on an integrated circuit* would rapidly double—from which we can easily infer that processing speed will increase.

[6] The Nielsen of Nielsen's Law.

[7] Bulk-up is a term coined for this report. It is meant to highlight the difference between how a bodybuilder consciously develops muscle ("bulks up") versus how most of us unconsciously simply put on fat as we age ("bloat"). However, this basic comparison must certainly have already been described somewhere; therefore, no credit is claimed for the underlying idea.

Despite bloat, the net effect of all these influences has been a rapid net *increase* over time in how much data the average computer can process and rapidly display. Transmission and processing speeds have finally grown to the point where enormously sophisticated graphical images can be transmitted to home users in seconds at affordable prices.

Net result. The net result of all these factors is the realization that we finally have the ability to generate and deliver large amounts of relatively low-cost, high-quality weather information. A "critical mass" has been achieved in terms of pilots being able to affordably see *the same kinds of high-level information that professional weather forecasters see*.

The Internet's Impact on Preflight Weather Briefing

Internet preflight weather briefing seems to be becoming quite popular, particularly among younger pilots. A recent study by Knecht (2008, Table 1) shows NOAA/NWS Internet briefing ranked #2 in relative overall value ("Rank") and perceived informational value ("Perceived value") by 230 GA pilots from five states (CA, OK, ND, IL, FL). Median pilot age was 23 (range 18-78), median flight experience, 245 h (range 15-18,000).

Considering everything just previously listed, we can assume that we are poised at a tipping point. Internet preflight weather self-briefing is already popular, and the supporting technology is becoming ever-faster and more powerful. Therefore, this popularity is almost certainly going to increase, making scientific study of this technology a timely topic for human factors research.

METHOD

Background

The current study was an exploratory project with two main objectives: a) to begin directly investigating how GA pilots interact with a PC "Internet-based weather information provider," and b) to start learning what kind of experimental equipment and methodology will be needed to collect accurate, meaningful, scientific data.

This experiment took place as part of a two-part longitudinal study conducted at the FAA's Civil Aerospace Medical Institute (CAMI) in Oklahoma City. Phase 1 examined data collected from January-July, 2008. Phase 2 data were collected July-September, 2008. Briefly, 50 GA pilot volunteers were selected to participate in Phase 1 with informed consent. Six were unable to participate in Phase 2, dropping the final N to 44. Half the pilots were instrument-rated, half were private pilots. Half were "local," defined as currently residing in Oklahoma. The other half were transported to CAMI by commercial carrier from a wide variety of locations around the U.S.

Apparatus and Procedure

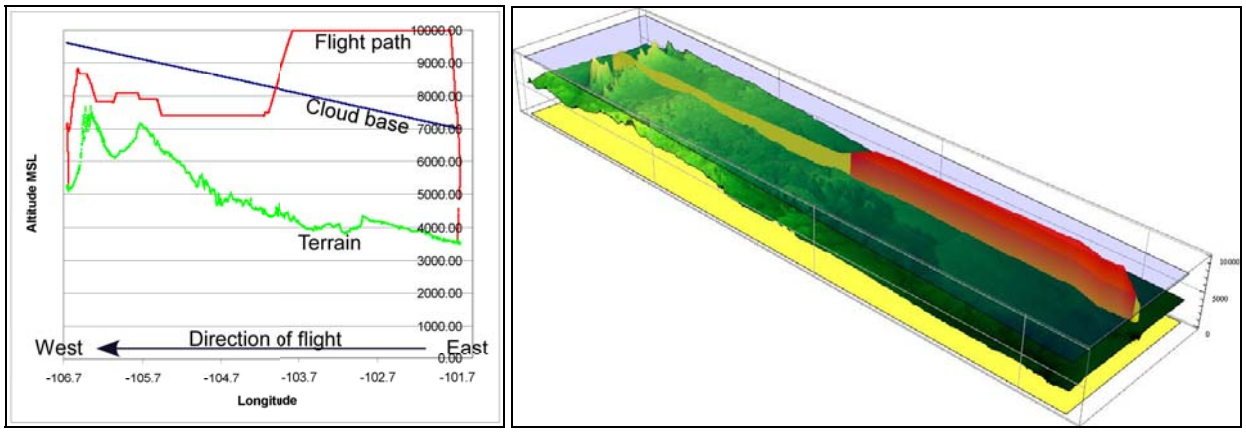
Flight simulator, mission, and terrain. As usual, *airframe*, *flight mission*, and *terrain* formed the context for the weather briefing. The airframe was the CAMI Advanced General Aviation Research Simulator (AGARS), configured as a Piper Malibu, a high-performance, propeller-driven small aircraft. The mission was instructed to be an east-to-west, 90-minute, visual-flight-rules (VFR) pleasure flight from Amarillo, TX (AMA) to Albuquerque, NM (ABQ).

Terrain and weather were used to dynamically increase pilot workload. Terrain gradually rose during the first two-thirds of the flight, followed by a dramatic elevation change during the last third. Meanwhile, a continuous layer of clouds also rose, but it rose less gradually than terrain. Figure 5 shows 2- and 3-D views of one pilot's actual flight profile.

The net result of the situation was to "squeeze" pilots between cloud bases and terrain, making for an increasingly difficult flight. Adding to the difficulty were deteriorating VFR weather conditions. Visibility began at 8 nautical miles (nm) and gradually decreased to 5 nm approximately two-thirds of the way along the route.

Table 1. Normalized ranks, values, frequency of use, and time spent using weather information providers.

Provider	Format	Rank 0-1	Perceived Value 0-1	Used on % of flights	Min spent when used	Est. ave. min spent
FSS (standard briefing)	telephone	1.0	1.0	61.5	9.1	5.6
Public NWS or NOAA site	**Internet**	**0.7**	**0.8**	**49.8**	**13.9**	**6.9**
DUATS	Internet	0.7	0.7	34.0	8.9	3.0
Commercial vendor	Internet	0.4	0.5	28.7	5.0	1.4
The Weather Channel	Internet, TV	0.4	0.5	27.9	7.0	2.0
FSS (outlook)	telephone	0.2	0.3	14.4	2.4	0.3
DUATS	at airport	0.1	0.1	11.3	2.1	0.2
FSS (automated TIBS)	telephone	0.1	0.1	8.9	1.5	0.1
FSS (abbreviated)	telephone	0.1	0.2	9.2	1.8	0.2
Other sources	telephone	0.0	0.0	4.3	0.6	0.0
			Total estimated length of wx brief per flight			**19.8**



a b

Figure 5. a) 2-D flight profile. The x-axis shows longitude; the y-axis shows aircraft altitude (ft above mean sea level); b) 3-D profile of the same flight. The translucent "glass sheet" represents the cloud base. Red droplines represent IMC penetration during this flight; yellow droplines represent flight in visual meteorological conditions (VMC).

Overall, this was a moderately difficult, dynamic weather situation, designed to gauge how pilots would react to conditions changing from easy to marginal VFR. Therefore, the preflight self-briefing became a critical feature of this mission. The better that briefing, the better the "mental model" a pilot would have to understand both the terrain and the potential weather over that terrain.

Emulation of aviationweather.gov. Key features of the popular NWS Web site, *www.aviationweather.gov,* were emulated by the author in *Microsoft Visual Studio 2005* . *Visual Studio* is a programming suite that enables creation of Hypertext Markup Language (html)-based Web pages with event-driven, dynamic content. Such emulated Web pages can react to mouseovers, mouse clicks and releases, and page-button clicks the same way actual Web pages do. With the addition of "code-behind,"[8] a program can, for instance, display flyout menus, popup message boxes, and play animated .gif movies. Moreover, code-behind can also record both *what* is acted upon onscreen and *when*, making it a useful experimental platform.

[8]Code-behind is computer code that "sits behind" the .html code that created the actual Web page. Within that html can lie embedded instructions, which then trigger the code-behind to execute functions and procedures the programmer has written. For instance, opening or closing a Web page can record the date and time, which can be used to calculate *pageview duration*, the length of time the person had that page open.

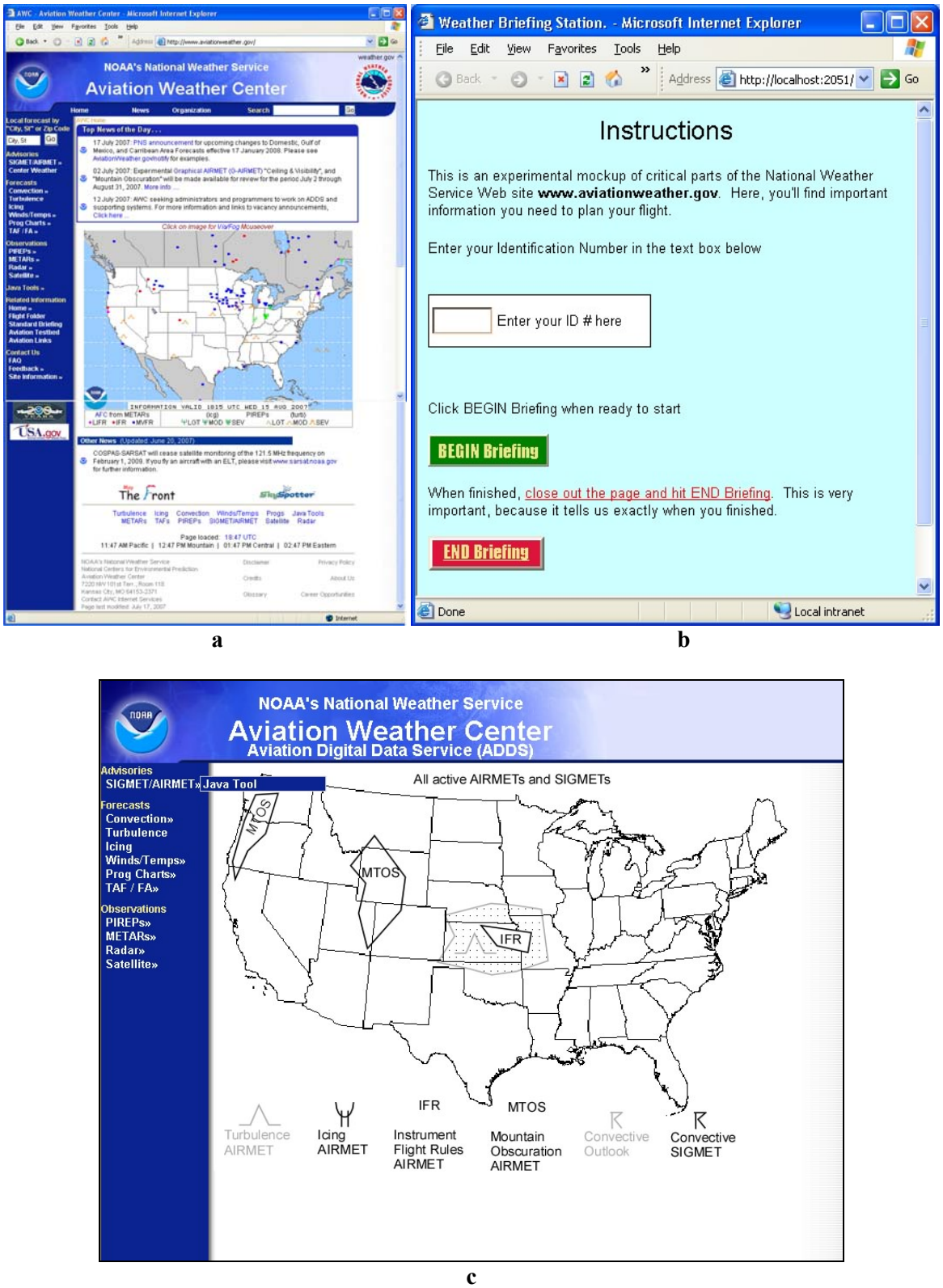


Figure 6. a) Home page of the real *aviationweather.gov* at the time the emulation was created; b) The experiment's opening screen; c) Emulation of a SIGMET/AIRMET.

Figure 6a shows the home page of the actual *aviationweather.gov* at the time the emulation was created. Figure 6b shows a screenshot of the experiment's opening screen, used to record a pilot's identification number and to begin or end the briefing. Figure 6c shows the emulation of a SIGMET/AIRMET, brought up by left-clicking on any page's left menu bar, moving the cursor to the resulting flyout menu, and then releasing the left mouse button.

Close resemblance between the real *aviationweather.gov* and our emulation was enabled by downloading sample NWS graphics and core html code (e.g., menus)—the computer instructions that created their Web pages.[9] Custom graphics of our scripted weather situation were then created with *Canvas* (ACD, 2005) and enhanced by adding JavaScript instructions to the html code, as well as buttons and hotspots responsive to Visual Studio code-behind. The intent was not to exactly duplicate *aviationweather.gov* but to emulate the basic look-and-feel and functionality of its menu and graphics.

Information content. Appendix A shows screenshots of the 18 Web pages used in the experiment. Separate pages were created for:

1) SIGMET[10]/AIRMET[11]...(Java tool) graphical
2) Convective SIGMETs graphical
3) CCFP[12]...graphical (looping animated .gif movie)
4) Convective outlook...graphical
   - 4.2 Categorical
   - 4.4 Tornado
   - 4.6 Hail
   - 4.8 Wind
5) Turbulence...graphical
6) Icing...graphical
7) Winds/Temps...text
8) Prog charts graphical
9) TAF[13]...Java tool graphical, with popup text
10) TAF Station model...graphical
11) FA[14]...text
12) PIREPs[15]...text (not used in this experiment)
13) METARs[16] (Java tool)...graphical, with popup text
14) Radar...graphical (looping NEXRAD[17] animated .gif movie)
15) Satellite...graphical (looping cloud cover animated .gif movie)

Animated .gif movies of NEXRAD images and satellite clouds were created by downloading individual images from weather data sites (*http://www.goes.noaa.gov/srchwest.html* and *http://radar.weather.gov/ridge/RadarImg/N0R/*). Separate, time-stamped frames were then collated in *Canvas* to create movies with controlled frame rates.

Dependent variables. Two primary dependent variables were examined in this study:

1. *Pageviews*: tallies of each page viewed by each pilot
2. *Pageview duration*: length of time each page was open for reading by each pilot

Total briefing time for each pilot was then generated as the sum of his or her individual page view durations.

Since this was only a preliminary study, sophisticated methods such as eye tracking were not employed. Such methods would be the next logical step, however, since knowing *what page has been opened* (pageviews), and *for how long it is viewed* (pageview duration), are *necessary* kinds of information—*but not sufficient* to fully know exactly what on a given page was viewed or what information was understood.[18]

[9]Because the National Weather Service is a U.S. government agency, its html code and graphics are public-domain.

[10]Significant Meteorological Information

[11]Airman's Meteorological Information

[12]Collaborative Convective Forecast Product

[13]Terminal Aerodrome Forecast

[14]FA=Aviation area 18-h forecast

[15]Pilot Report

[16]Meteorological Aviation Report

[17]Next Generation Radar

[18]Even knowing what content was viewed on a page does not guarantee that the viewer *understood* what was viewed. This is clearly a difficult problem. Yet, we have to start somewhere if we want to understand and improve preflight self-briefing.

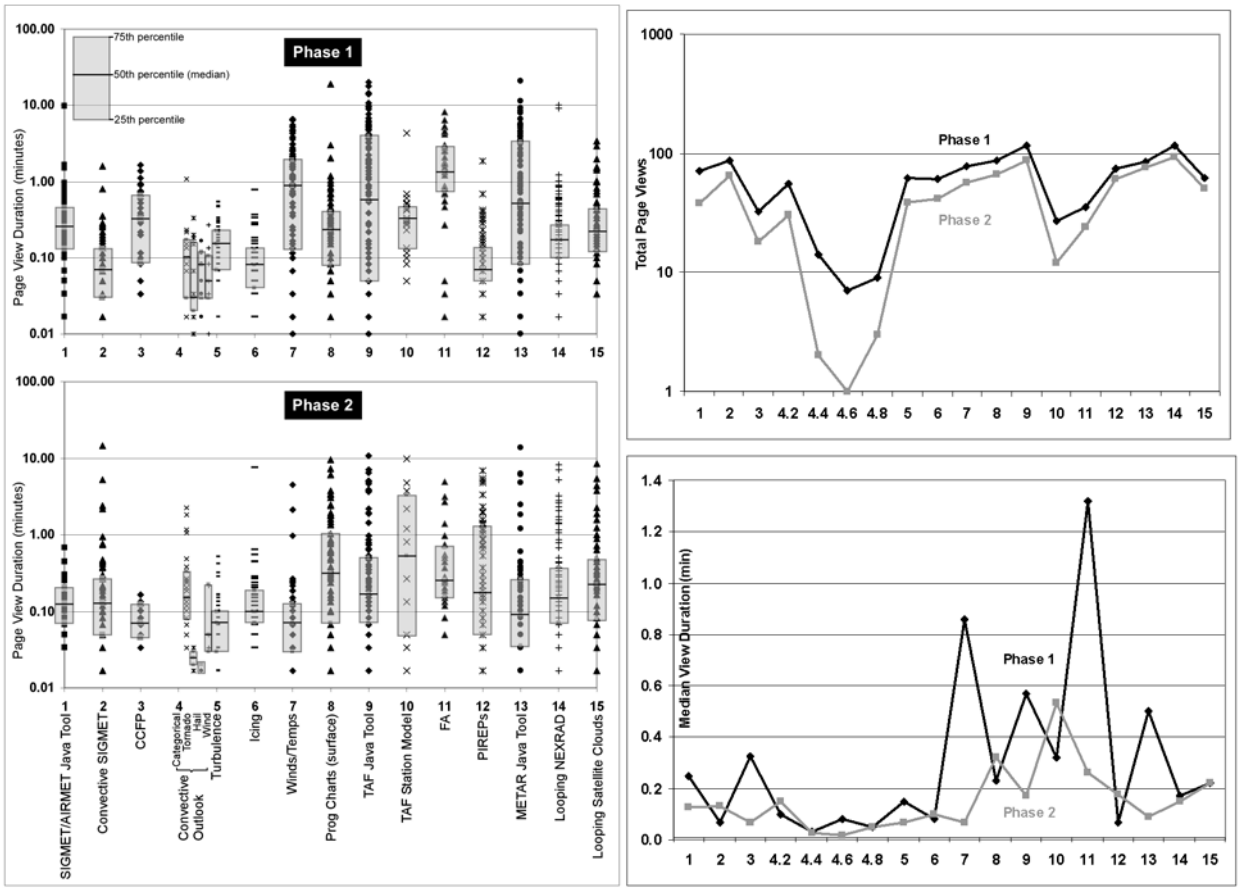


Figure 7. (Left). Pageview duration frequency distributions for the part-task emulation of aviationweather.gov. (Left, top) Phase 1 (N=50). (Left, bottom) Phase 2 (N=44). (Right, bottom) Pageview durations (medians only). (Right, top) Total page views. The y-axis represents total number of times each page was viewed by all pilots (Phase 2 values adjusted for attrition).

RESULTS

Distributional Normality of Data

Pageviews and pageview duration both produced frequency distributions (e.g., Figure 7, left). Ideally, such distributions should be normal (bell-shaped) about their means to justify the use of parametric statistics.

However, in both Phases 1 and 2, the Web-emulation page view duration data were distinctly non-normal. Some pages were open for very little time while a few were open for extraordinarily long times. In particular, some of the longest viewing times reflected either pilots forgetting to close out the last page after finishing the briefing or else moving back and forth between the computer and the sectional during the briefing.

Given this non-normality, means and mean-based statistics were shunned in favor of rank- and median[19]-based (nonparametric) statistics. These are less powerful, statistically, but more robust to deviant distributions and data outliers.

Specific Observations

How Web preflight briefing changes over time. Patterns of page usage varied from Phase 1 to Phase 2. Figure 7 (left) compares Phase 1 pageview durations (left, top) with Phase 2 (left, bottom). The logarithmic y-axis makes it easier to discriminate small values while still representing large values. Box plots show 25th, 50th (median), and 75th percentiles. By comparing groupwise medians (rather than means), we expect more stable pagewise viewing estimates, since the effect of outliers is reduced.

Figure 7 (left) shows all the data but is admittedly complex and confusing. Therefore, Figure 7 (right, bottom) depicts the same data, but simplified, showing only groupwise medians.

These data form two patterns, one for each phase of the experiment. Phase 1-2 correlation can, therefore, estimate *consistency-over-time* for median pageview durations.[20]

[19]The median is the mid-point of a group of scores, above and below which half the score values lie.

[20]These medians are based upon pilots who actually viewed those pages (as opposed to the alternate technique of padding distributions with zeros to reflect non-viewing pilots).

Pageview duration showed no significant consistency over time ($p_{Wilcoxon}$ = .14, NS).[21] Some pages were viewed longer in Phase 2, others less.

However, *page preferences (Total page views,* Fig. 7, right, top*) remained remarkably consistent over time* ($r_{Spearman}$ = .972, p <.000001). In other words, given similar weather situations, pilots tended to consistently seek out *certain kinds* of information. They just did not necessarily spend consistent *amounts of time* viewing that information.

Evidence of learning. Next, notice the significant *decrease in page views* from Phase 1 to Phase 2, averaging over 20%, $p_{Wilcoxon}$ = .0002).[22] This probably does not mean that pilots started disregarding their preflight weather briefings in Phase 2. It probably only means that pilots had already used the computerized system once and were showing increasing skill using the system the second time around.

Information accessible from the top-level menu in one operation may be more likely to be accessed than information that requires multiple operations. This is an important human factors hypothesis that should be further investigated. Figure 7 (right, top and bottom) shows that the page 4 variants (convective outlook) were low-view and low-duration pages in both Phases 1 and 2—except for the "Categorical" page (page "4.2"). The Categorical page was the default, and the other three page 4 variants had to be accessed by way of buttons on the Categorical page. Hence, this indicates that most pilots simply never pressed those buttons. This could imply that ease-of-access is a critical aspect of design, or it could simply mean that, given this particular flight, the information on those particular pages was judged not particularly useful by most pilots.

Page popularity versus difficulty. In a sense, some pages did seem "more popular" than others. As mentioned, the page 4 variants (Convective Outlook) uniformly received very few views. In contrast, pages 9 (TAF Java Tool) and 14 (Looping NEXRAD) received the highest number of views.

Examining this issue of "popularity" more deeply, we can assume that people tend to dwell on things they find either

1. highly informative or
2. hard to understand

Unfortunately, explanation 1 implies something good, explanation 2 not so good. Moreover, either explanation—or both—may be confounded in any given pilot for any given page. This confound will have to be untangled in future studies using more sophisticated methods.

For now, let us just imagine a simple "group dwell index," calculated by multiplying each page's total group number of *page views* times its median view *duration*. *Dwell* can then estimate "group attention paid to each page," which can serve as a temporary proxy for either "popularity" or "difficulty," to be determined at a later date.

$$Dwell = \tilde{N}_i * \tilde{T}_i \qquad (1)$$

where N = the *i*th page's number of views and T = view duration (~ above a variable is the symbol for "median"). Figure 8 illustrates. Figure 8a may or may not support the point made previously about the importance of page design (this needs further investigation). The three page-4 non-default variants (that took more effort to access) had far lower dwell. As previously mentioned, these required a button click, and many pilots simply ignored the buttons. Figure 8b shows clearly how pages tended to cluster into two groups, high- versus low-dwell.

Table 2 shows Phase 2 pages ranked by dwell. Of those, Figure 9 illustrates the three highest-ranked pages.

METARs (page 13) and TAFs (page 9) lost dwell in Phase 2. That decrease probably reflected increased pilot skill in using the mouseover popup text on those two pages, which may have been initially confusing. Nonetheless, METARs and TAFs still remained above the median in dwell in both phases.

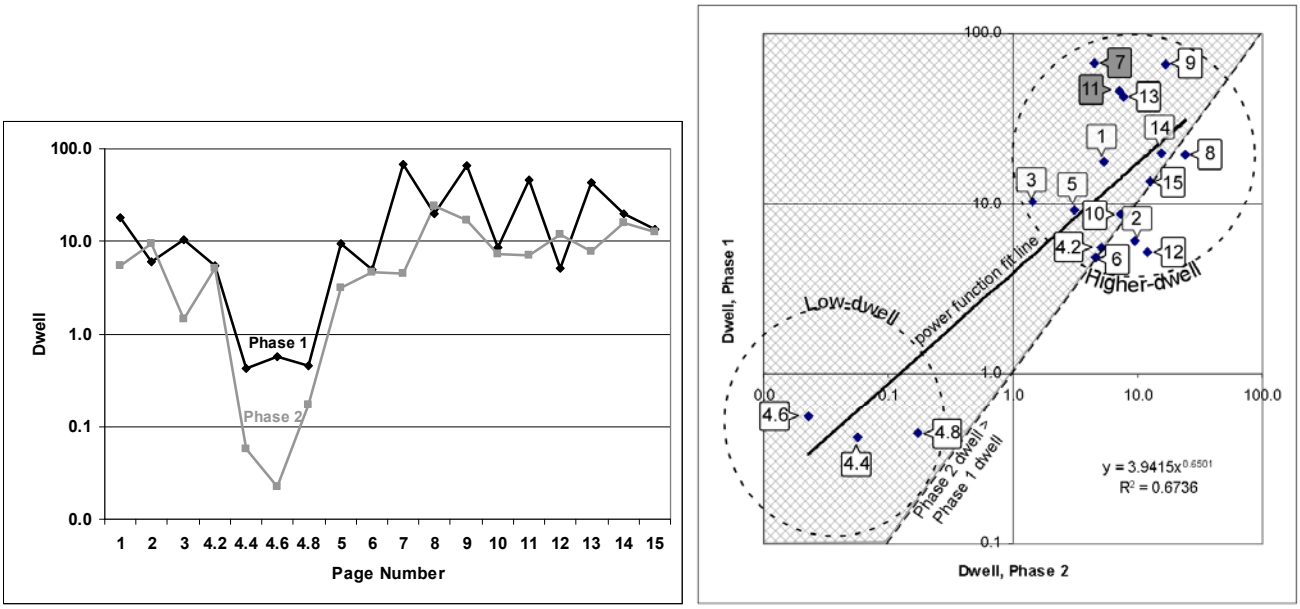
Effect of Web preflight briefing time on subsequent flight safety. One could argue that briefing is as briefing does. This means we should try to assess what effect the quality of a preflight briefing has on subsequent flight safety.

The results of this study imply that the mere *quantity* of preflight weather self-briefing is not synonymous with its *quality*. Total briefing time (*Web preflight duration*) may be the simplest candidate for a metric of "quality." Yet, the sheer amount of time pilots spent on preflight weather briefing did not seem to influence their safety record later during the flight. Correlations of Web preflight duration with safety variables such as flight duration (here, a proxy for degree of penetration into deteriorating weather), minimum distance to ABQ, minutes scud running, minutes in IMC, and minutes < 500' AGL, were all non-significant, with r-values ranging from $-.076 \le r_s \le .109$.

Durable relations between variables. There were two aspects of the briefing that did relate to pilot demographic variables. If we define a "durable" relation as one remaining statistically significant across both Phases 1 and 2,

[21]This was partly due to huge decreases in Phase 2 median view duration for two outliers—pages 7 and 11—the only two text-based pages (all others were graphical). Page 7 was winds/temps as text; page 11 was the area forecast (FA) as text. From this, we might be tempted to argue that text-based products are less efficient than graphical products, but that would not take into account differences in the amount of information per page. Plus, when pages 7 and 11 are ignored, $r_{Spearman}$ ® .399—less of a change than we might expect.

[22]The statistical significance was not just trivially due to the loss of 6 pilots in Phase 2. The vertical (y) axis of Figure 3 (right) is corrected for attrition (Phase 2 page views were multiplied by 50/44).



a b

Figure 8. a) Page dwell (Equation 1); b) Log-log scatterplot of Phase 1 by Phase 2 dwell, with power function best-fit line. Pages below the dashed identity line (e.g., 8, 2, 15) gained dwell in Phase 2. Again, all Phase 2 values were adjusted for pilot attrition.

Table 2. Phase-2 page dwell, rank-ordered.

Page	**8**	**9**	**14**	**15**	**12**	**2**	**13**	**10**	**11**	**Median**	**1**	**4.2**	**6**	**7**	**5**	**3**	**4.8**	**4.4**	**4.6**
Name	Prog Charts (Surface)	TAF Java Tool	Looping NEXRAD	Looping Satellite Clouds	PIREPs	Convective SIGMET	METAR Java Tool	TAF Station Model	FA		SIGMET/AIRMET	Convective Outlook (Categorical)	Icing	Winds/Temps	Turbulence	CCFP	Convective Outlook (Wind)	Convective Outlook (Tornado)	Convective Outlook (Hail)
Dwell	**24.4**	**16.8**	**15.7**	12.8	11.9	9.6	7.8	7.3	7.1		5.4	5.1	4.7	4.5	3.1	1.4	0.2	0.1	0.0

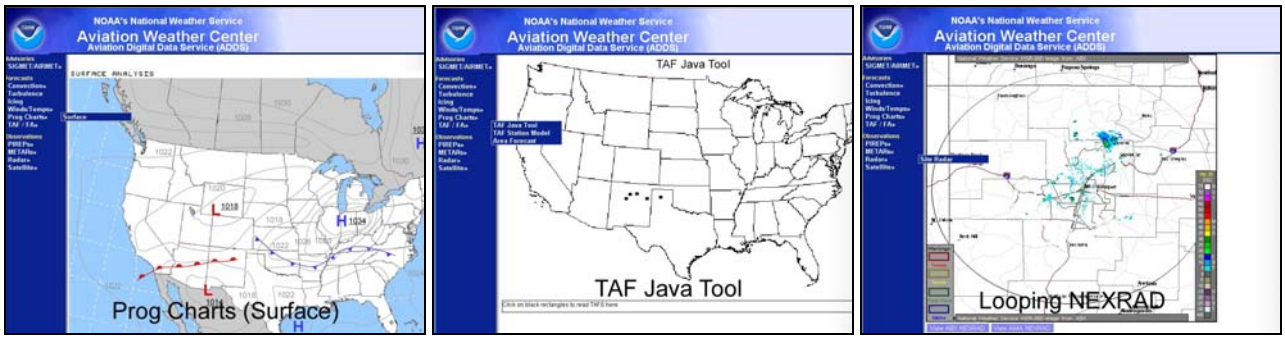


Figure 9. Phase 2's three highest-dwell pages.

Table 3. Durable, non-trivial relations between Phases 1 and 2 variables.

Variable 1	Variable 2: Locality of Residence (1=Local)[a]	Variable 2: Pilot Age[b]
Web Preflight Duration	**-.348 (p=.013) Ph1** **-.421 (p=.004) Ph2**	**.417 (p=.003) Ph1** **.475 (p=.001) Ph2**

[a] r_{pb} = Point-biserial. [b] r_s = Spearman rho. *P*-values are in parentheses.

then Table 3 shows the two durable correlations observed between preflight briefing and pilot demographics.

Table 3 shows that both *local* pilots and *younger* pilots spent slightly less time on their Web weather preflight briefing. However, this is not surprising. Local pilots were likely just more familiar with local terrain and weather patterns. And, older pilots may have been either slightly more careful briefers, or they might have simply been a bit less familiar with Web-based briefing (or with *aviationweather.gov* itself).

If there is a message in these durable relations, it is that preflight briefing systems need to be designed to accommodate not just the technologically sophisticated user but also the less sophisticated user.

DISCUSSION

Motivation for This Study

The Internet has become increasingly capable, affordable, and popular. Internet-based preflight weather self-briefing is following suit. Therefore, the motivation for this research was to begin systematic investigation of how modern Web-based weather products are being used by GA pilots during this kind of briefing.

Method

An experimental, data-gathering emulation of the National Weather Service Web site *www.aviationweather.gov* was written by the author for use on a standalone PC. This was tested for use with 2 similar, challenging weather scenarios involving 50 GA pilots in simulated cross-country VFR flight. Each pilot made a total of 2 flights, separated by several months. Each flight employed 1 of 2 similar weather scenarios, with the Web emulation used as the pilots' sole preflight weather briefing source. Eighteen Web pages were created to display weather information for each scenario, each page emulating a similar category of product shown by *aviationweather.gov*.

Measurements. Two dependent variables were measured—*page views* (which pages each pilot viewed) and *pageview duration* (how long each page was viewed). *Total briefing time* was then calculated for each pilot by summing pageview durations. A groupwise "dwell" index was also derived for each Web page by multiplying the group's page views times its median pageview durations. Dwell then could serve as a proxy for either "popularity" or "difficulty" (see below).

Methodological difficulties discovered. Three main methodological difficulties were discovered. First, a small-but-significant number of pilots failed to close out their briefing session after finishing, and/or divided their time between the computer and the sectional. Both cases led to the same problem—that recorded pageview durations occasionally did not reflect actual viewing times, leading to data non-normality. Fortunately, this problem was minimized by the use of median-based statistics, which are more robust to data non-normality and outliers.

Second, pageview durations and total briefing time are not necessarily synonymous with *quality of briefing*. "Quality" will eventually need to be assessed more directly by other methods: for instance, by eye-tracking and by post-briefing knowledge tests. Quality can also be indirectly assessed (as was done here) by correlating aspects of the preflight briefing with objective behavioral measures of subsequent flight performance (e.g., terrain and ground clearance, penetration distance into decreasing visibility, and so forth).

Third, longer pageview durations do not necessarily mean that a given page is highly informative. It can simply mean that the page is difficult to understand. Again, more sophisticated methods will be required to sort out this confound.

Main Findings

First and foremost, this Web emulation was successfully used by these pilots as a standalone preflight weather self-briefing source. As an experimental platform, it enabled objective performance data-capture in tab-delimited text file formats exportable to spreadsheets and statistical programs. As far as we know, this is the first such experimental platform devised for the express purpose of testing Web-based preflight weather briefing.

After data analysis, a number of specific findings emerged. First, given a specific flight mission, we found

that, *as a group*, GA pilots seemed significantly consistent over time in the *kinds of information* they sought out. However, the *amount of time* they spent examining that information seemed to vary over time, even given similar flight situations.

Second, pilots seem to have favorite information sources (e.g., graphical prog charts, TAFs, NEXRAD, and satellite cloud images). Yet, we should expect those favorites to shift somewhat, depending on the flight mission. Since only one basic type of mission was tested here, further research is necessary on this topic.

Third, Web page design is potentially important. For example, pages not accessible from the top-level menu may be ignored or overlooked.

These findings are important to weather information providers because the ability to display certain types of information—and certain ways of displaying it—are sure to give the knowledgeable provider an advantage over competitors. The key will be highly informative pages that still remain easy to understand.

S*econdary findings.* As expected, skill at using the system appears to improve with practice.

There were also slight-but-significant tendencies for older pilots and out-of-town pilots to spend a bit more time on their preflight briefing. Older pilots probably have slightly lower average computer skills and may be more used to getting briefed by the Flight Service Station. Additionally, the greater briefing times of out-of-town pilots were probably merely due to their being less familiar with the local geography and weather patterns.

Future Directions

During this experiment, many pilots informally expressed the opinion that the future of weather briefing looks increasingly Internet-based, as opposed to coming solely from the Flight Service Station. The rapid development of Internet technology certainly supports these opinions.

If the future truly is Web-based, then pilot training will need to address these new technologies and trends. Pilots will need to become skilled at self-briefing through products such as *aviationweather.gov*. Hence, these products themselves should become the subject of human factors research through such methods as content analysis and usability testing.

More specifically, we suspect that graphical display of information is superior to text display. This is an empirical issue that should be tested, since the current study does not directly address that hypothesis.

Similarly, other aspects of page design should be explored. A series of usability tests could be devised to maximize information relevance and optimize ease-of-use.

Metrics of briefing quality are needed. Page views and pageview duration are interesting—but not definitive—measures of what a pilot gets out of a briefing. Eye tracking could allow a cross-check of how much attention is being paid to an overall page, as well as to specific parts of that page. Short questions could also be created to test pilot situational knowledge. Finally, these measures could be correlated with objective, behavioral flight safety measures to test if "briefing is as briefing does."

Other testable ideas are *user-configurable displays* (ones capable of giving the user a choice of how information will be displayed) and *4D route-planning displays*[23] —ones that give a sense of *what* weather may be encountered *where* and *when* along a selected route, given the aircraft speed, planned altitude, and direction of travel of both aircraft and weather systems.

[23]Route-planning displays, such as the Flight Path Tool, are currently being developed and fielded by the Aviation Digital Data Service (ADDS, http://weather.aero/)—a partnership between NOAA's Forecast Systems Laboratory, the National Center for Atmospheric Research (NCAR) Research Applications Program, and the National Centers for Environmental Prediction (NCEP) Aviation Weather Center.

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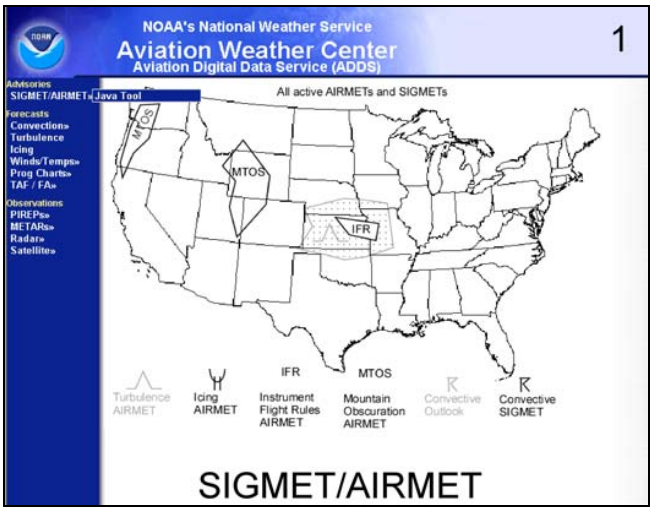
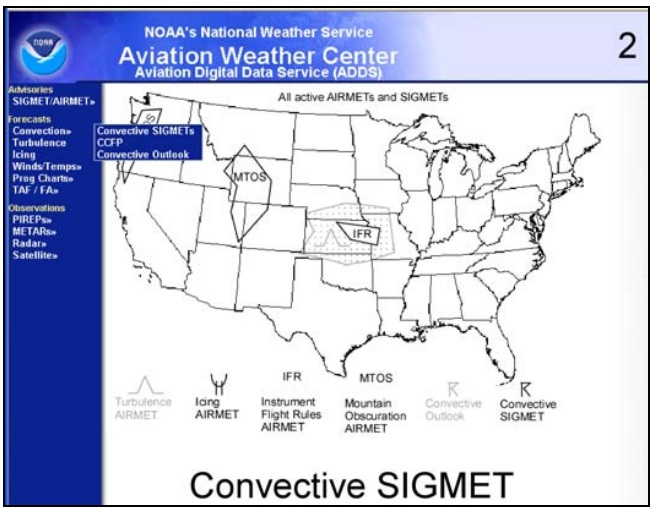
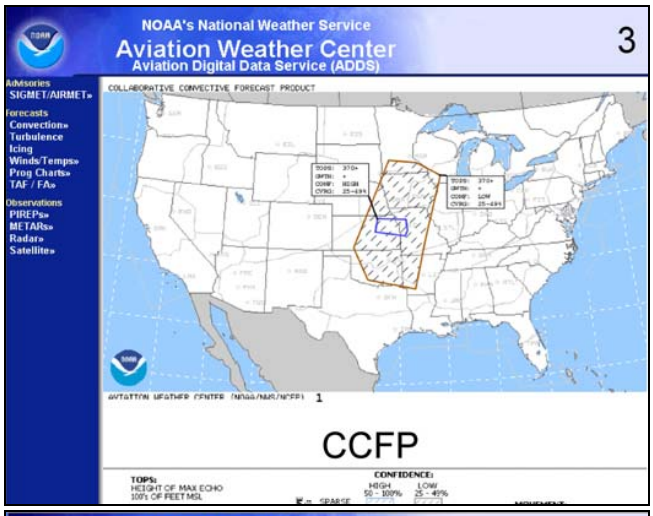
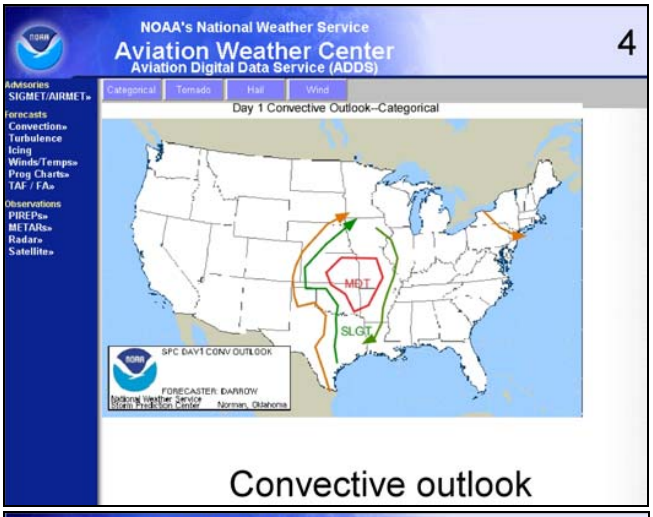
[24]Nielsenwire is a publication of the Nielsen Company, the global media research company, and is unaffiliated with the J. Nielsen of "Nielsen's Law."

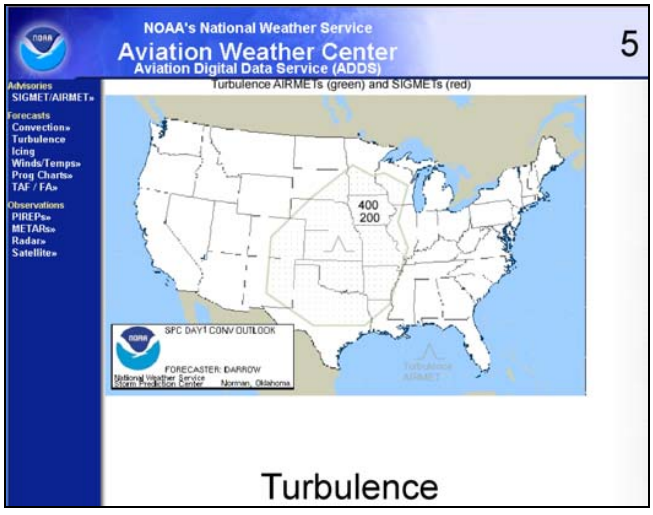
APPENDIX A
Web Preflight Briefing Screenshots

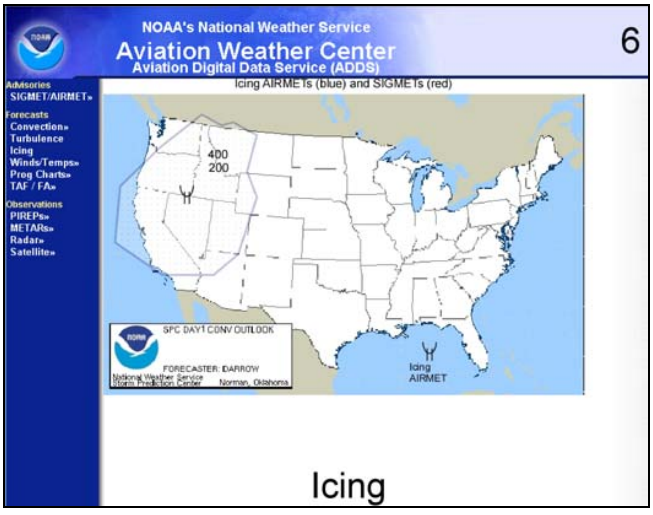


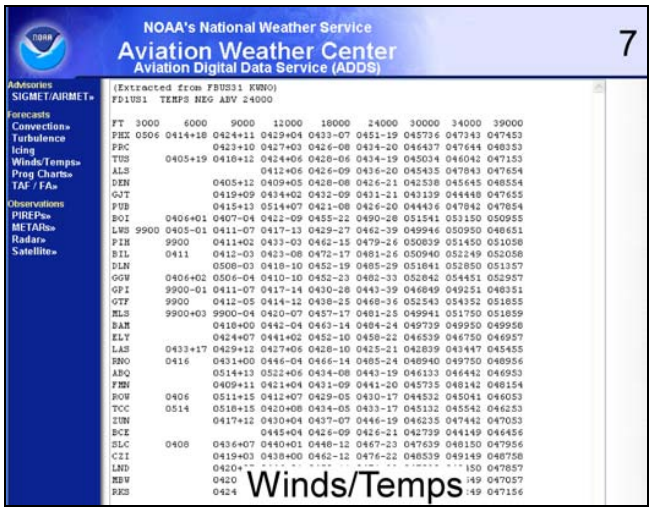


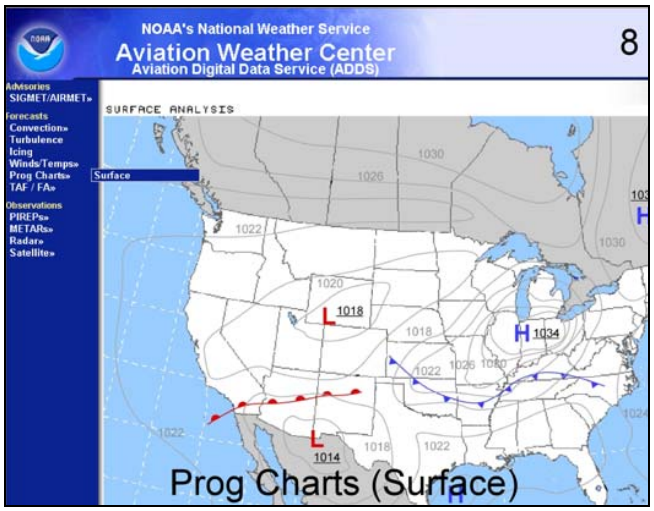


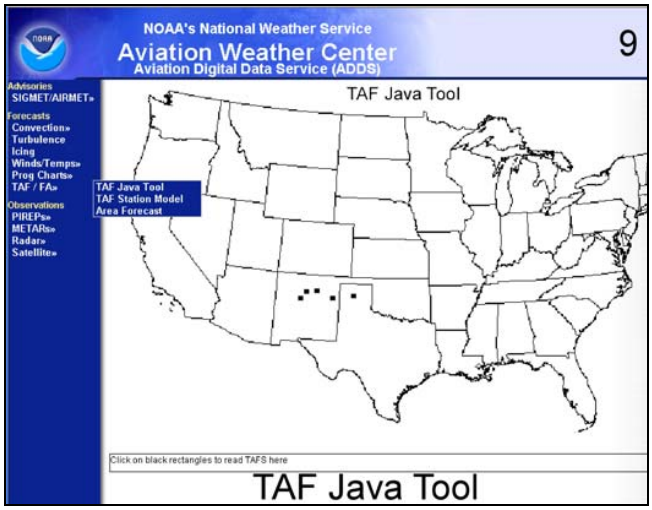


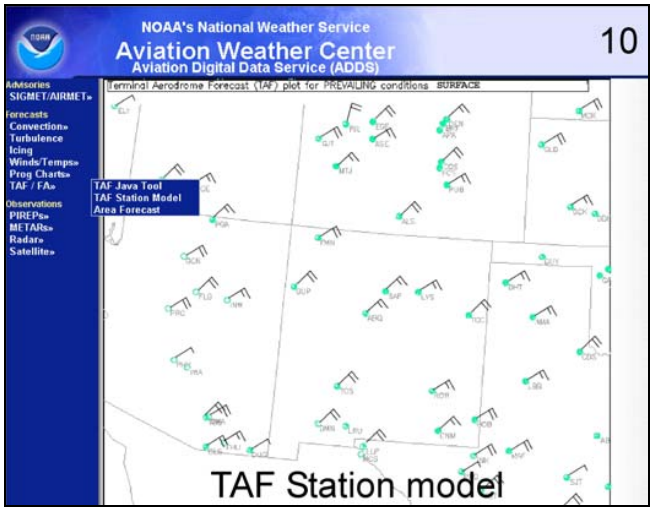


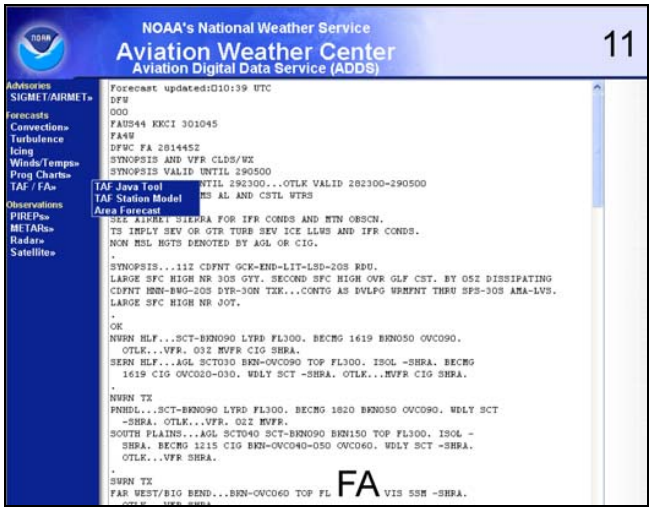


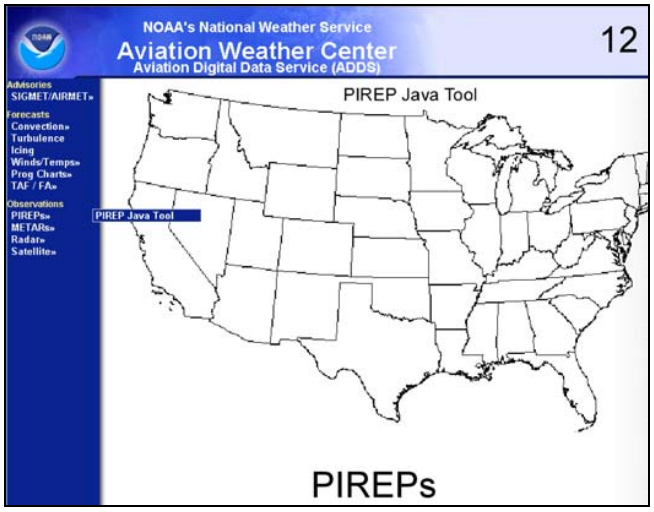

NOAA's National Weather Service
Aviation Weather Center
Aviation Digital Data Service (ADDS)
7
Winds/Temps


NOAA's National Weather Service
Aviation Weather Center
Aviation Digital Data Service (ADDS)
8
SURFACE ANALYSIS
Surface
Prog Charts (Surface)


NOAA's National Weather Service
Aviation Weather Center
Aviation Digital Data Service (ADDS)
9
TAF Java Tool
TAF Java Tool
TAF Station Model
Area Forecast
Click on black rectangles to read TAFS here
TAF Java Tool


NOAA's National Weather Service
Aviation Weather Center
Aviation Digital Data Service (ADDS)
10
Terminal Aerodrome Forecast (TAF) plot for PREVAILING conditions SURFACE
TAF Java Tool
TAF Station Model
Area Forecast
TAF Station model


NOAA's National Weather Service
Aviation Weather Center
Aviation Digital Data Service (ADDS)
11
Forecast updated:010:39 UTC
TAF Java Tool
TAF Station Model
Area Forecast
FA


NOAA's National Weather Service
Aviation Weather Center
Aviation Digital Data Service (ADDS)
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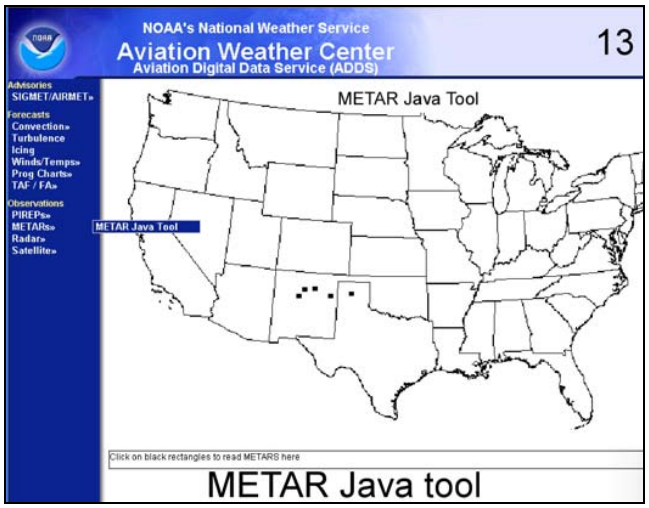
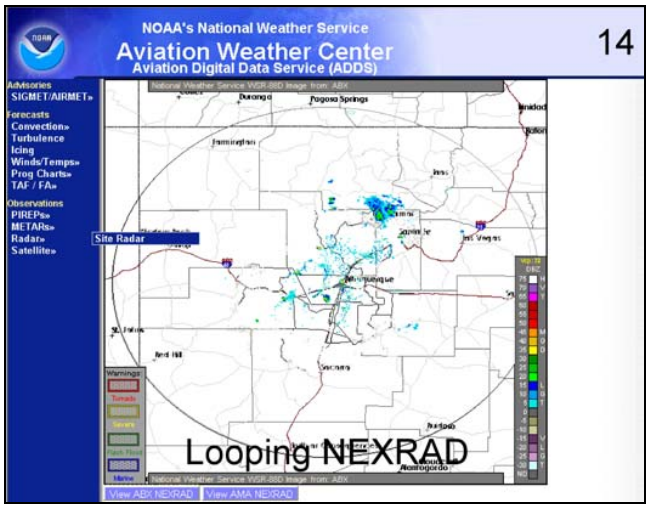
PIREP Java Tool
PIREP Java Tool
PIREPs


NOAA's National Weather Service
Aviation Weather Center
Aviation Digital Data Service (ADDS)
13
Advisories
SIGMET/AIRMET»
Forecasts
Convection»
Turbulence
Icing
Winds/Temps»
Prog Charts»
TAF / FA»
Observations
PIREPs»
METARs»
Radar»
Satellite»
METAR Java Tool
METAR Java Tool
Click on black rectangles to read METARS here
METAR Java tool


NOAA's National Weather Service
Aviation Weather Center
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Advisories
SIGMET/AIRMET»
Forecasts
Convection»
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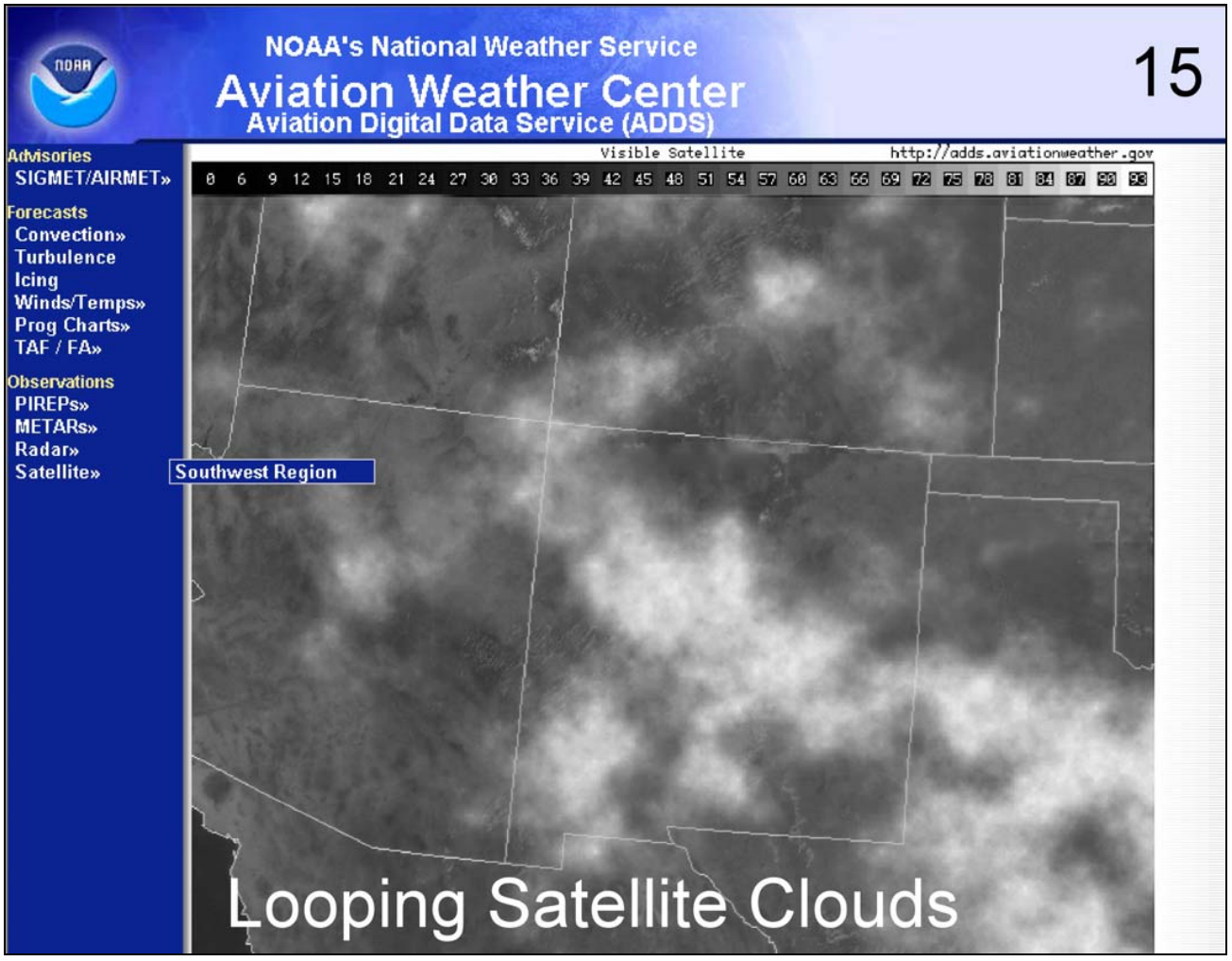
METARs»
Radar»
Satellite»
Site Radar
Looping NEXRAD


NOAA's National Weather Service
Aviation Weather Center
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15
Advisories
SIGMET/AIRMET»
Forecasts
Convection»
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http://adds.aviationweather.gov
0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93
Southwest Region
Looping Satellite Clouds