SkyScope: An Aviation Weather Visualization Tool

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Abstract

It is critically important that pilots of small aircraft fully understand weather conditions in order to plan a safe flight. Many such pilots fly by visual reference to the ground and cannot enter clouds. Online weather data is available to assist pilots with planning flights in order to avoid poor conditions. However, this data is provided in an extremely terse and cryptic format. The reports are time consuming to decode and impose a high cognitive load. We introduce the SkyScope visualization that plots weather information on timelines using graphical indicators. We believe SkyScope allows pilots to more quickly and easily determine if weather conditions are suitable for a particular flight.

Introduction

A thorough understanding of weather conditions is of critical importance for conducting a safe flight in a small airplane. Most small aircraft pilots fly and navigate by visual reference to the ground rather than by using instruments. Flights in this category are governed by Visual Flight Rules (VFR) and cannot fly in clouds or above cloud ceilings. Flights in this category are often further restricted by the aircraft and pilot's ability to handle other weather conditions such as high winds. Accurately assessing weather conditions is therefore a critical part of planning a safe VFR flight.

A variety of weather information services are available to assist pilots with flight planning. These services include weather information that is available online. Online routine weather observations called METARs and airport forecasts called TAFs are particularly useful for VFR pilots. Reading METAR and TAF data for airports along a proposed route can give pilots valuable information that is necessary for safe flight planning.

METARs typically report conditions observed at an airport on the hour and are available for the past three hours. Additional METARs are issued at any time when weather conditions are changing rapidly. Therefore, each station will typically have 3 – 6 METARs associated with it. The following information is provided in each METAR:

- Wind speed and direction
- Visibility

- Precipitation or other weather conditions
- Cloud layers including altitude and amount of sky cover
- Temperature and dew point
- Air pressure

A TAF is also available for most airports. This forecast is valid for 6, 12, or 24 hours, depending on the airport. TAFs are composed of an initial forecast similar to a METAR observation followed by a set of "change groups" that indicate weather changes during the validity period of the forecast.

There are several types of TAF change groups that complicate their interpretation. Some groups indicate permanent changes while others are temporary or only have a 30-40% chance of occurring. Furthermore, some groups provide full weather data while others only specify incremental changes to the previous group. A typical TAF has between 3 and 6 change groups which can occur at any time during the forecast period.

Unfortunately, METARs and TAFs are provided in an extremely terse and cryptic format. Many abbreviations are used and it is necessary to know the details of the format and implied information in order to interpret the meaning of the characters. For example, the sequence `261139Z 261212` found at the beginning of a TAF is decodes to "This report was issued on the 26th day of the month at 11:39 UTC and is valid from the 26th at 12:00 to the 27th day of the month at 12:00."

Figure 1 is an example of the METAR and TAF data for just three airports. Pilots will often require information for several more airports for long flights.

```
ABBOTSFORD/BC
METAR CYXX 260100Z 00000KT 25SM -RA FEW025 BKN040 OVC060 07/04 A2945
RMK SF1SC6SC2 SLP973=
METAR CYXX 260200Z 36002KT 30SM SCT040 BKN070 OVC100 07/03 A2941 RMK
SC3AC2AC2 OCNL LGT RA SLP962=
METAR CYXX 260300Z 02003KT 15SM -RA BKN040 OVC070 07/03 A2941 RMK
SC6AC2 SLP959=

TAF CYXX 252343Z 260024 03010KT P6SM -RA SCT030 BKN050 OVC070 TEMPO
0007 5SM -RA BR BKN025
FM0700Z 03005KT P6SM SCT030 BKN050 TEMPO 0724 P6SM -SHRA BKN030
BECMG 1416 07010KT
RMK NXT FCST BY 06Z=

VANCOUVER/VANCOUVER INTL/BC
METAR CYVR 260100Z 09014G19KT 12SM -SHRA SCT025 OVC040 07/04 A2944
RMK SF3SC5 SLP969=
METAR CYVR 260200Z 08011G16KT 15SM -SHRA SCT025 OVC040 07/04 A2942
RMK SC3SC5 SLP963=
METAR CYVR 260300Z 06005KT 15SM -SHRA FEW025 BKN040 OVC055 07/04
A2941 RMK SF2SC5SC2 PCPN VRY LGT SLP959=
SPECI CYVR 260312Z 05007KT 15SM FEW025 BKN040 OVC055 RMK SF2SC5SC2=
```

```
TAF CYVR 260250Z 260324 09012G22KT P6SM -RA SCT020 BKN040 OVC070
TEMPO 0306 5SM -RA BR BKN020 OVC040
FM0600Z 09012G22KT P6SM SCT025 BKN040
TEMPO 0612 6SM -SHRA BR BKN025
FM1200Z 09010KT P6SM SCT020 BKN040 OVC060
TEMPO 1220 4SM -SHRA BR BKN020 OVC040
FM2000Z VRB03KT P6SM BKN040 TEMPO 2024 P6SM -SHRA
BECMG 2123 31008KT
RMK NXT FCST BY 06Z=

NANAIMO/BC
METAR CYCD 260100Z 00000KT 8SM -RA FEW008 BKN028 OVC050 06/05 A2944
RMK SF1SC6SC1 SLP970=
METAR CYCD 260200Z 00000KT 10SM -RA MIFG FEW006 BKN028 OVC050 05/05
A2941 RMK SF1SC5SC2 SLP961=
METAR CYCD 260300Z 00000KT 6SM -RA BR FEW006 SCT010 BKN014 OVC040
05/05 A2942 RMK SF2ST2SC3SC1 SLP962=

TAF CYCD 260135Z 260205 16005KT P6SM -SHRA SCT010 BKN025 OVC050 TEMPO
0205 4SM -SHRA BR SCT010 BKN020
RMK NXT FCST WILL BE ISSUED AT 261545Z=
```

Figure 1: METAR and TAF data for three airports.

Given a data set such as in Figure 1, the pilot's task is to decode and synthesize this information to generate a mental picture of the weather conditions. The mental weather picture should include not only the weather for several airports, but also the weather for each airport at multiple times in the future. Additionally, the forecasted time of each weather occurrence at each airport must be converted from Universal Coordinated Time (UTC) to local time.

There are several drawbacks to using reports given in this format. Decoding this information is time consuming and imposes a high cognitive load. Furthermore, it is difficult to remember information for the previous airport when decoding the next airport's forecast. Another drawback is that important weather condition trends are difficult to spot. Finally, it is necessary to be thoroughly trained in order to correctly perform the weather data decoding.

These limitations suggest that an alternative representation of these data would be beneficial. We propose a graphical layout of METAR and TAF data and provide an implementation called SkyScope that produces this graphical layout from standard METAR and TAF data.

SkyScope

SkyScope is a Java implementation that generates the proposed graphical METAR and TAF information visualization. The input to the SkyScope program is the standard text METAR and TAF data available online [4].

The SkyScope visualization approach is to present weather information as "weather glyphs" plotted on a timeline stack. In this visualization, a horizontal timeline is used to anchor METAR observations and TAF forecasts for a particular airport. Timelines for additional airports are arranged in a vertical stack.

Weather Glyphs

Weather glyphs are collections of graphical indicators that are designed to convey weather information in an intuitive and rapidly accessible way. The glyphs are plotted on the appropriate airport's timeline at the observed or forecasted time. Each indicator is briefly described below. Figure 2 provides an annotated example of a weather glyph.

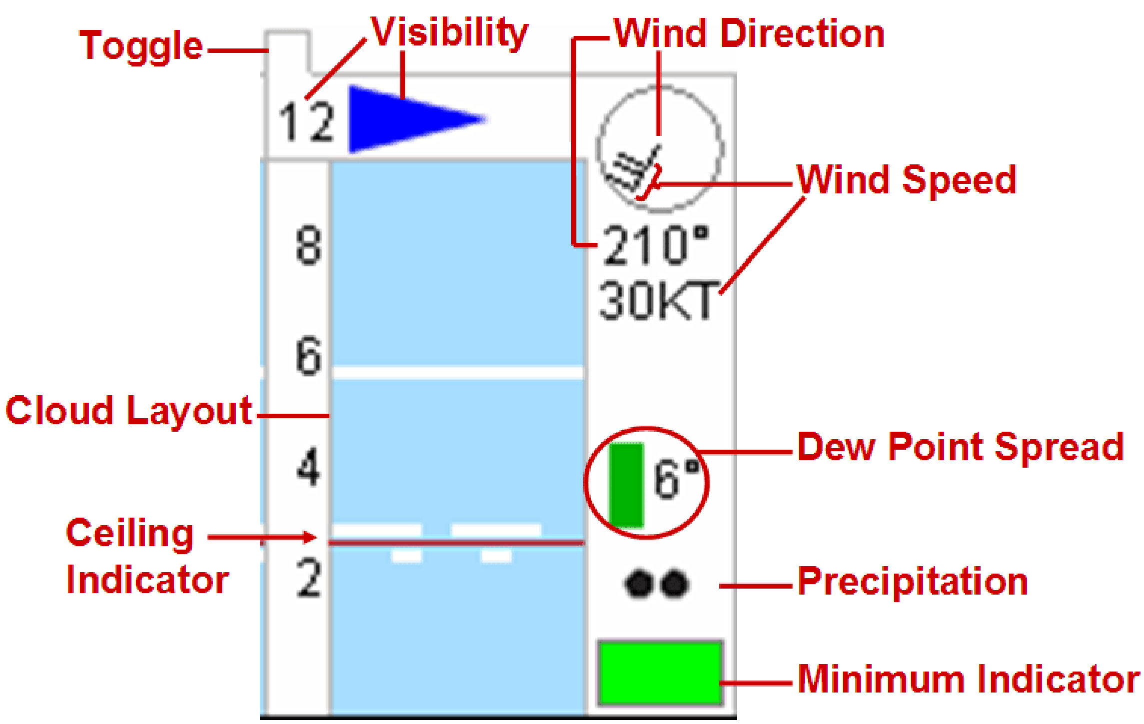

Figure 2. Annotated weather glyph

<u>Cloud Layers</u>
The nature and altitude of cloud layers is among the most critical information required for safe VFR flight. The weather glyph displays cloud layers as white horizontal bands on a sky-coloured background. The bands are positioned at the reported or forecast altitude, which is read from a vertical scale on the left. The amount of a band that is visible is proportional to the amount of the sky that is covered by that layer. For example, a "scattered" layer occupies 4/8 of the sky by definition. Therefore, horizontal bands representing scattered layers are 50% filled in. The cloud layout also includes a red horizontal line indicating the ceiling altitude, if a ceiling exists.

Wind Speed & Direction

Wind speed and direction are both displayed graphically and with exact values. The graphical representation for wind direction is a line extending from the center of a circle in the direction of the wind. The circle is intended to be representative of a compass. Wind speed is indicated graphically by annotating the end of the wind direction line with perpendicular lines. Long perpendicular lines represent 10 knots of wind and a short line represents 5 knots. The wind speed is the sum of the values of the perpendicular lines. For example, if a wind direction line has two long and one short perpendicular line, the wind speed is 25 knots. This approach is a standard technique used on some aviation weather maps.

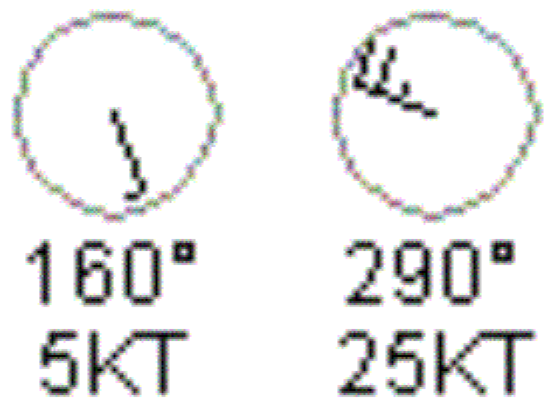

Fig. 3. Wind speed and direction indicator examples.

Visibility

Visibility is indicated with a blue right-pointing triangle. Longer triangles represent higher visibility while shorter triangles indicate low visibility. A triangle was chosen because narrowing to a point is reminiscent of visibility that diminishes with distance. The visibility is also displayed as a number beside the visibility triangle.

Precipitation

When precipitation or other weather conditions such as fog or mist are present, a symbol corresponding to the particular phenomenon is displayed in the weather glyph. The symbols used are standard symbols used on aviation weather maps. Although some symbols are not intuitive (i.e. two dots for rain), common symbols are easily learned and pilots who know the standard symbols will be immediately familiar with them. Furthermore, it is possible to extend SkyScope to show a tool tip with a full text description when the user hovers over a symbol.

Temperature & Dew Point

METAR observations report both the observed temperature and the dew point. The dew point is the temperature at which the air will become saturated with moisture and most likely lead to the formation of clouds or fog. The spread between the current temperature and dew point is therefore a critical measure of safety for VFR flights. Since the actual temperature is much less important, we elected to graphically depict only the dew point spread. The spread is shown as a number in degrees as well as with a vertical bar. Tall vertical bars indicate a large spread relative to other observations. The colour green is often representative of safety we have therefore coloured the spread bar in green. Larger bars with more green surface area indicate larger spreads that are more safe for VFR flights.

Minimum Condition Indicator

The weather glyph also contains a “minimum condition indicator” that appears as a red or green rectangle. By default, the indicator appears in green if the weather conditions presented by the glyph are considered safe for VFR flight. Otherwise, the indicator will appear in red. This indicator is also used for displaying the results of dynamic minimum condition queries as described in the Minimum Condition Querying section.

Weather Glyph Layout

Weather glyphs corresponding to observations or forecasted conditions are drawn on the timeline so that the glyph begins at the relevant UTC time of day. For ease of use, the local time corresponding to the UTC time is also shown in parentheses below the UTC time.

Although METARs are observations at an instant in time, their glyphs are one hour wide on the timeline. Although this is technically somewhat incorrect, the glyph will in fact be representative of conditions over the entire hour. This is because any significant change in conditions during the hour will be reported with an additional METAR (and glyph) part-way through the hour. When a METAR is reported part-way through an hour, its glyph will occlude part of the previous glyph. In this case it is often still possible to see the cloud layout and visibility, but other indicators will be occluded. When this occurs, a toggle tab will appear in the upper-left corner of occluded glyphs so that by clicking the tab, they can be made visible for more thorough inspection.

Weather Glyphs representing TAFs are similarly drawn with a width on one timeline hour. This is appropriate since forecasted conditions are always forecast to exist for at least one hour. When the forecasted conditions are expected to persist for longer, a validity period indicator is used to show how these conditions extend to a time in the future. This indicator is a simple horizontal bar extending until the time at which the weather conditions are no longer in effect.

This layout allows trends in several weather conditions to be easily spotted by scanning glyphs from left to right. For example, it is easy to spot trends toward increasing cloud with a steadily lowering ceiling – a potentially hazardous condition for VFR pilots. Similarly, trends in visibility, wind speed and direction, and dew point spread are clearly visible.

Minimum Condition Querying

There is no standard set of minimum weather conditions that is suitable for all VFR flights. Required conditions depend on the purpose of the flight, pilot skill, aircraft, and other factors. For example, an inexperienced pilot on a sight-seeing flight will require far better conditions than a pilot who is commuting along a familiar route.

Support for different sets of minimum conditions is provided by SkyScope using a variation of dynamic querying [6]. Users can open a Minimum Conditions dialog box that contains sliders that allow them to set their preferences on the following criteria:

- Minimum ceiling altitude
- Minimum visibility
- Maximum wind speed
- Minimum Temperature - dew point spread

Adjusting these sliders causes the minimum condition indicator on each weather glyph to dynamically update. This indicator appears in red if any weather condition is outside the specified limit or in green if the weather is suitable given the slider positions. This allows for preattentive [7] perception of where and when suitable or unsuitable conditions prevail. See Figure 4 for a screenshot of the minimum conditions dialog box.

The minimum conditions dialog box also allows the user to select preset minimum condition values that correspond to well-known limits. The preset values are:

- VFR – Conditions suitable for VFR flights.
- MVFR – Marginal VFR. These conditions are considered poor but still legal for VFR flights.
- IFR – Conditions suitable for pilots capable of operating under Instrument Flight Rules. IFR pilots can fly by reference to instruments rather than visual contact with the ground.

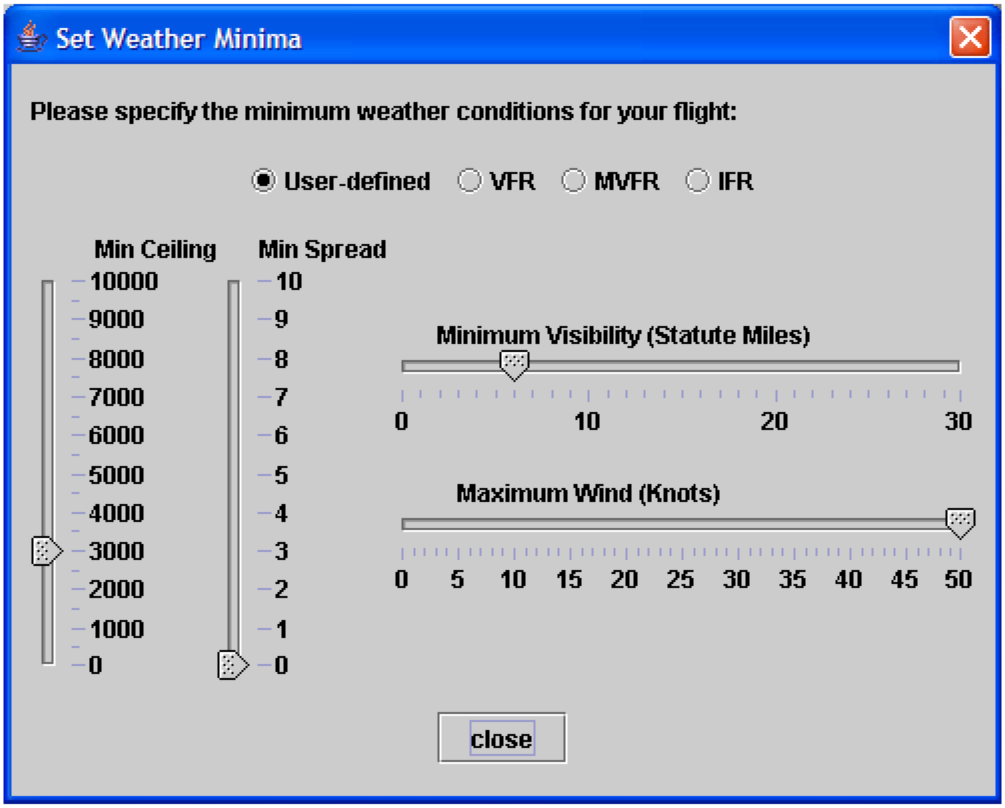

Figure 4. Set Minimum Conditions Dialog Box

When the minimum condition indicator for a glyph turns red, pilots will often want to know which weather condition(s) were below the specified minimums. Therefore, the indicators corresponding to unmet minimum conditions will also appear in red when the minimum condition indicator is red. This allows users to quickly see the cause of the poor conditions.

Adjusting Maximum Cloud Display Altitude

SkyScope provides a slider that allows users to adjust the maximum altitude of clouds that are displayed in the weather glyphs. This feature allows the system to display both high altitude clouds as well as the details of low level clouds with a limited amount of screen space. For example, an aerial tour pilot may need to be aware of clouds at high altitudes. This pilot can slide the maximum altitude slider to the top to see clouds as high as 12,000 feet. Alternatively, an air taxi pilot may be operating in poor conditions and need to know the exact altitudes of low level clouds. This pilot can slide the maximum altitude slider down toward lower altitudes. This will cause higher altitudes to be ignored and increase the scale of the display at lower altitudes. This feature adds flexibility to the SkyScope display, allowing it to be useful in more situations.

High-Level Implementation

SkyScope has been implemented in Java using 33 classes and requiring approximately 5000 lines of code. Java was selected primarily because the Java2D graphics library is suitable for drawing the proposed visualization. It is also important that Java is platform independent since we expect that SkyScope will be a usable and useful tool for a significant number of users.

The SkyScope system has two major components, a weather data parser and a weather data visualizer. The parser reads raw text METAR and TAF data and produces a data structure representing the information. The visualizer is essentially composed of a hierarchy of figures containing sub-figures. Each figure typically has a reference to a corresponding data structure object that the figure is responsible for drawing. This visualization is driven and displayed in a GUI implemented in Java Swing.

Sample Usage Scenarios

In this section, we describe three scenarios in which SkyScope can be of valuable assistance to pilots.

1. Short High Altitude, Sight-seeing Flight

Pilot John A. Viator has a couple of friends visiting and wants to take them on a aerial sightseeing tour between Vancouver and Victoria. Before doing so, John decides to use SkyScope to check the weather and determine if conditions are suitable for him to fly. John goes to the NAVCANADA website and retrieves the weather reports for Vancouver and Victoria in METAR and TAF standard text format. He then runs the SkyScope program and pastes the relevant weather data text into the Text Weather portion of the program. He then clicks on the Visualization tab to display the visualized weather reports. Before analyzing the weather reports, John opens the Set Minimum Conditions dialog box and adjusts the minimum conditions sliders to values suitable for sight-seeing. Thus, John increases the Minimum Visibility slider so that he and his friends can catch the sights below and decreases the Maximum Wind slider so that their flight is not too turbulent. After setting the minimum conditions, John goes back to the visualization and adjusts the Maximum Altitude slider. The Maximum Altitude Slider adjusts the maximum altitude that the Cloud Layout displays. Since John intends to do some sight-seeing, he slides the slider all the way to the top so that he can see of cloud layers at the higher altitudes. This allows John to determine if he can fly high enough to have a good view of the sights below without being obstructed by clouds. John looks for weather trends at the Vancouver and Victoria airports by scanning the METAR weather glyphs of each respective airport from left to right. He then determines that the weather at both locations appears to be improving. Furthermore, John analyses the TAF forecast glyphs and find that they have a green minimum indicator, indicating that all of the previously specified conditions are met. John also finds that he would be able to fly high enough to catch some spectacular sights, without being obstructed by clouds.

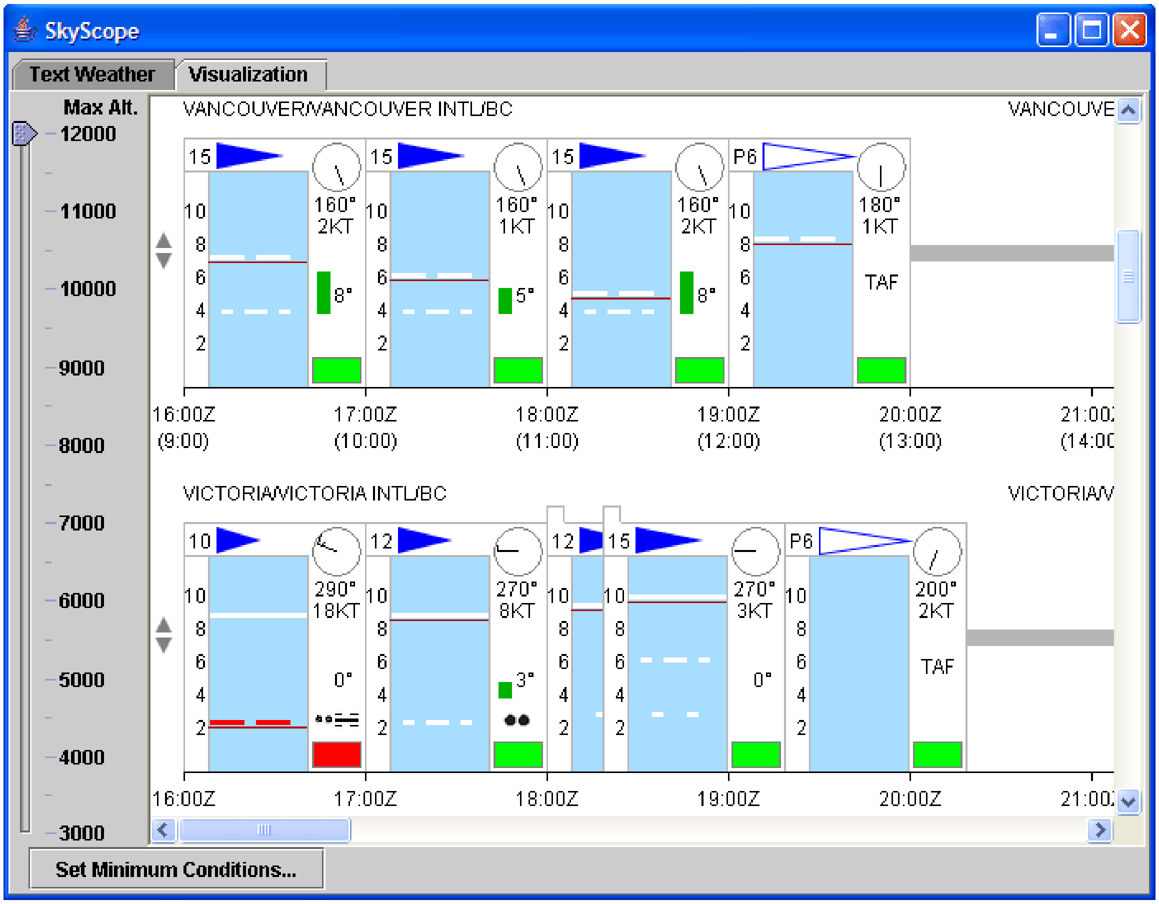

Figure 5: Screenshot of Scenario 1

2. Long Cross-Country Flight

This time, John needs to plan a long cross-country flight that would require him to fly by five different airports, A, B, C, D, E. Again, John begins by retrieving the necessary METAR and TAF text from NAVCANADA and copies them into SkyScope. This time, John does not require the same type of conditions as he did for sight-seeing. So, he makes sure to set the minimum conditions to Visual Flight Rules (VFR). John then looks at the visualization and finds that the vertical placement of the airports is not in the sequence that he would be encountering them. Thus, he uses the reordering buttons on the left hand side of the visualization to reorder the airports into the order he will fly over tem. John then vertically scans for the weather condition at his expected arrival time at each airport. While doing so, John looks airport E's weather conditions at 3:35pm PST, his estimated time of arrival, and is alerted that the minimum indicator is red. John examines that particular weather glyph closer and notes that the wind speed and visibility are red in colour, indicating that these are the components that failed the VFR conditions. John also drags the Maximum Altitude Slider to a low level in order to "zoom" in on the lower altitude cloud layers for that particular time and airport. Upon examining this, John finds that there are too many low clouds, and given the bad visibility and high wind speed, decides that he would not be able to fly into airport E between 3pm and 5pm. However, the forecast for airport E's weather after 5pm is promising and the minimum indicator displays green. Therefore, John plans to arrive at airport D at 4pm and stop there for something to eat before leaving for airport E at 5pm, thus avoiding the unsuitable weather between 3pm and 5pm.

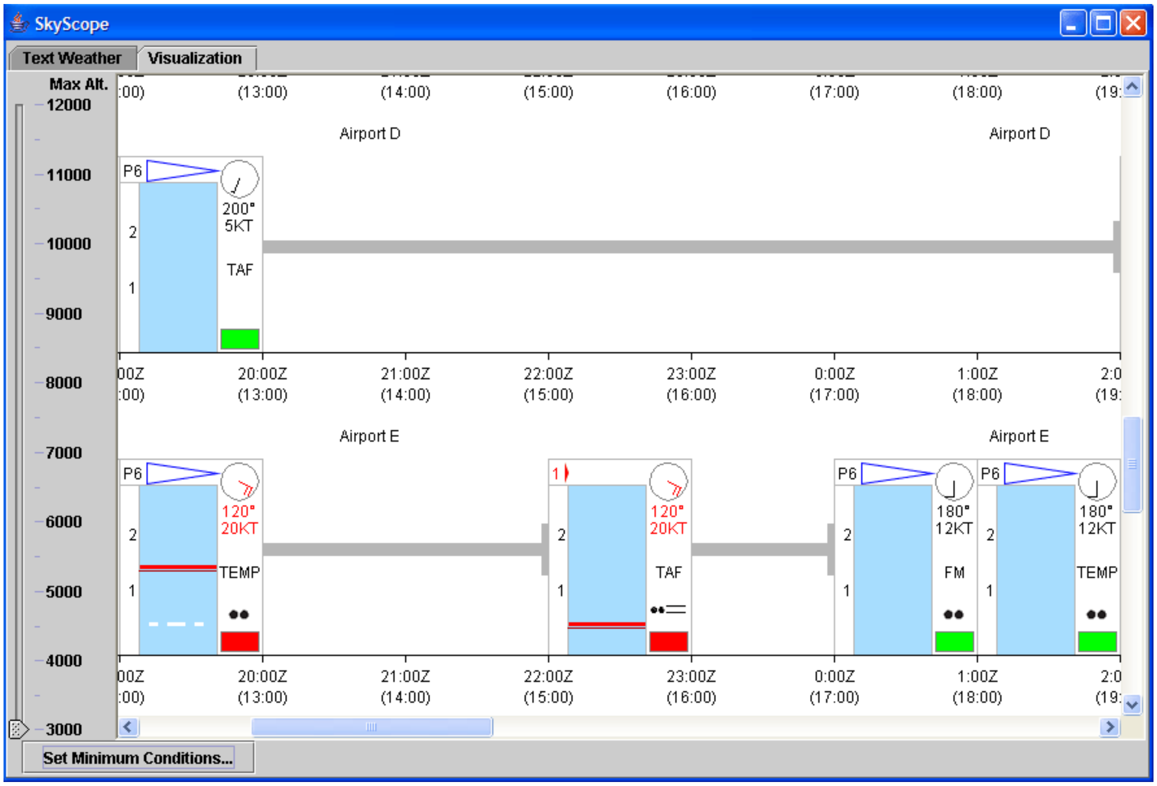

Figure 6: Screenshot of Scenario 2

3. Learning Tool for Student Pilots

Another SkyScope usage scenario was inspired by one of the flight instructors we interviewed. In this scenario, SkyScope is used as a learning aid for those new to METAR and TAF text reports. Given the rather cryptic nature of the raw METAR and TAF text, students may find it difficult to learn how to read them. Moreover, they may have little confidence in their understanding of the METAR and TAF because of their unfamiliarity with the encoding. Thus, the SkyScope program could be used to verify that the student's decoding of the METAR and TAF text is correct. For example, by looking at the visualized cloud layout, users can develop a better sense of the cloud layers as they learn to interpret the corresponding text format. Other components of the weather glyph can similarly be used to confirm the student's decoding of the corresponding text. When planning flights, SkyScope's customizable minimum conditions settings can be used to ensure that only flights in ideal conditions are attempted, despite the student's lack of familiarity with text weather reports.

Related Work

Several tools are available for helping pilots visualize weather data relevant for both in-flight and flight planning purposes. However, these tools address different problems and do not offer the same level of detail and ease-of-use that SkyScope provides.

The most relevant existing tool is the GTAF program [3]. This program takes as input METAR and TAF messages and displays a snapshot of the weather conditions for several locations at a particular time. This snapshot display does not allow the user to identify trends and plan a flight – instead, the user can only tell what the weather conditions are at any given time.
In contrast, SkyScope arranges the weather reports of each airport location in a timeline and stacks the timeline of each airport on top of each other. By doing so, SkyScope allows users to easily see trends across a timeline and also compare weather conditions between different locations. The GTAF program also does not visualize several important components of the weather report. For example, visibility, wind speed and direction are components that the GTAF program leaves in their raw text format. The text representation requires the user to read and decode the textual information, a costly operation that SkyScope alleviates by representing the information graphically. The GTAF program also has a static scale for their altitude display – thus, users are not able to "zoom" into lower altitudes. SkyScope allows users to dynamically adjust the scale of the cloud layout display and also draws the ceiling on the cloud layout for a more comprehensive view of the sky condition.

The FlightMax EX500 [2] is a tool that aids pilots during flight by providing up-to-date radar, weather, navigation, lighting, traffic, and terrain information in a visualized format. The FlightMax EX500 tool allows users to specify origin and destination locations for display but can only display the weather report for a single location at any given time. This limitation makes the FlightMax EX500 unsuitable for flight planning – which is what SkyScope is particular well-suited for. Moreover, the FlightMax EX500 does not visualize the METAR/TAF information, but instead interprets and displays them in a more readable text form.

Weather View 32 [8] is a customizable tool that allows users to select what information they would like to be displayed. However, the Weather View 32 program is a general weather visualization program, not specific to aviation, and thus oversimplifies concepts that are crucial to flight planning. For example, cloud layout cannot be visualized with the Weather View 32, and precipitation is overly simplified into only fifteen program-specific icons, whereas METAR/TAF reports have a vocabulary upwards of fifty-nine distinct precipitation conditions (with combinations of the conditions allowed as well). The SkyScope program uses standard weather symbols, which many pilots are already familiar with, to display precipitation conditions – thus allowing for more specific conditions to be discerned. Currently, SkyScope displays twenty-seven distinct precipitation conditions graphically, and other conditions can be displayed in text format.

The Graphical Forecast Area (GFA) is a standard weather tool for aviators and is available from the NAVCANADA website [4]. The GFA provides a weather map showing large-scale weather conditions over a large region. In the GFA, details of particular stations are not displayed. Moreover, the GFA does not allow the user to perform side-by-side comparisons of different weather conditions across regions.

Glyphs have been used in many visualization tools. They are used to visualize such abstract concepts as the number of lines in a program, type of file, and historical information of files [1]. The core of the SkyScope program is the Weather Report Glyph (See Figure 2). Each Weather Report Glyph represents weather conditions observed or forecasted for a particular time. The various components of the glyph provide an intuitive, easy to read, visual representation of their corresponding weather conditions. The visualization of the weather reports allows users to avoid the task of decoding the raw METAR and TAF text. Moreover, by placing weather glyphs side by side or stacking them vertically, tasks such as trend identification and inter-airport weather comparison become easier.

Timelines have been a popular method for displaying time-series data [5]. With timelines, the chronological relationships between the plotted elements are easy to see and understand. Furthermore, since weather reports are time-sensitive data, placing them on timelines allow for users to see trends in the weather and also logically "step" through the various reports and forecasts via horizontal scrolling.

Evaluation

We have implemented a functional SkyScope prototype that can successfully parse and visualize METAR and TAF data downloaded from the Internet [4]. We believe that the visualization approach is a substantial improvement over the existing text representations of METAR and TAF data. Furthermore, the advantage gained from using the tool far outweighs the time required to copy and paste data into it. Although the approach has weaknesses, the feedback from potential users regarding SkyScope has been overwhelmingly positive. This suggests that pilots agree that the tool provides a valuable service. We believe it is likely that the visualization approach introduced by SkyScope will become a commonly used tool for aviation flight planning.

Informal User Feedback

We followed an iterative design process and therefore consulted with actual pilots during the design and implementation phases. This feedback has guided the visualization design from paper prototype to working implementation. Many of the features in the final implementation resulted from discussions with licensed pilots. However, the overall concept of displaying glyphs on a timeline was well accepted and did not change during development.

Informal user feedback has provided an initial subjective basis for evaluating the tool's utility. Two pilots we spoke with during the conceptual phase were enthusiastic about the proposed system. Later, we used a laptop to demonstrate SkyScope to three flight instructors at a local airport. All three liked the idea and two were particularly enthusiastic about its potential as a flight planning tool. We also demonstrated the system to the captain of a large passenger jet. He had many suggestions for improving and extending the tool and felt that the overall concept was sound. Several of the interviewed pilots indicated that they would like this system to be made available for online access alongside existing sources of aviation weather data.

SkyScope Strengths

The main strength of the SkyScope system is the speed with which a user can assess weather conditions across airports and times of day. After setting the minimum condition preferences, a user can find areas of poor conditions almost preattentively. Text weather data, however, requires a significant investment of time to decode.

Another important advantage of this approach is that it is easy to use. Substantial expertise is required to decode and interpret text weather data. With SkyScope, novice users will immediately be able to interpret most of the provided weather information. This is in part due to the intuitive use of colour. For example, a white band on a blue background denotes a cloud layer. This ease of use makes a complete weather picture available to a broader set of users.

A strength of the timeline layout is that trends in weather conditions can be easily detected by scanning glyphs from left to right. Finding trends in text data requires a tedious process of repeatedly checking each report's value for a particular parameter.

While the visualization itself provides many advantages over text data, additional features of the SkyScope tool allow it the flexibility to be used for planning flights with different weather condition requirements. For example, the maximum altitude displayed can be adjusted to show high clouds or a more accurate view of low-level clouds. Similarly, the sliders in the minimum conditions dialog box allow users to specify the exact conditions that are required for their type of flight.

SkyScope Weaknesses

Despite its improvements over raw text, the SkyScope visualization approach has several weaknesses. One important limitation is the amount of screen space that is required for drawing weather glyphs at the appropriate time on a timeline. There is often substantial unused space between glyphs and this forces the user to scroll around the visualization. The glyphs themselves also require a significant area of the screen to display information.

While the timeline approach results in empty space between TAF glyphs, it can also cause occluded glyphs if more than one METAR is issued in an hour. This occlusion can slow the process of reading the weather if the user is required to click individual tabs to bring glyphs into view.

The visualization makes extensive use of the colour green to denote good conditions and red to denote poor conditions. While this colour mapping is intuitive, it is not suitable for people with red-green colour-blindness.

Finally, some users may find it confusing that weather glyphs occupy an hour of space on the time line. In particular METAR reports actually represent the weather at an instant in time.

Lessons Learned

Developing the SkyScope visualization has been a substantial learning experience for the authors. The following issues illustrate some particularly important lessons:

- Iterative design works. We were able to meet with potential users throughout the design process. These meetings resulted in substantial changes to the system that substantially improved its usability.
- Screen space is a constrained resource. Our initial design did not consider screen space as a limitation and the final result, though usable, is not a particularly compact representation. More emphasis on screen utilization may have lead to a more scalable overview + detail approach.
- It is difficult to determine when to use a visual indicator, text, or both. User studies are required to determine if some text can be removed to save screen space.
- It is difficult to select colours that intuitively suggest "good" or "bad" without using red and green, which are indistinguishable to many people with colour-blindness.
- Most potential users we spoke with requested additional weather data from other weather reports to be integrated with the SkyScope display. We anticipate that the screen would soon become cluttered with information. It would be difficult to provide filtering or customization mechanisms to mitigate this problem.

Future Work

The current implementation of SkyScope is sufficient for visualizing basic METAR and TAF data. However, there are several ways in which work could continue in order to improve the tool.

A logical next step would be to perform a formal user study. It would be relatively straight-forward to conduct a study comparing the effectiveness of this visualization with that of using text weather reports. Subjects with and without SkyScope could be given a flight planning problem to solve. The solution quality and time required could then be compared across with-SkyScope and without-SkyScope groups. Although it may seem clear that the SkyScope group would be more successful, such a study would be useful for quantifying exactly how much improvement can be gained by using SkyScope.

If the effectiveness of SkyScope can be confirmed, it would be worthwhile to develop views that require less screen space and scrolling. Such views could take the form of overview + detail approaches or mechanisms for collapsing unused timeline space.

Finally, there are many additional features that have been requested by potential users that may improve SkyScope's ability to assist with flight planning such as:

- Tool tips that contain text information corresponding to graphical indicators
- Drawing clouds that look like their actual type (stratus, cumulus, cirrus)
- Overlaying runway layouts on the wind direction indicator
- Support for printing visualizations for in-flight use

Conclusion

We have developed the SkyScope visualization tool for aviation weather data. We believe this tool provides a novel, useful, and more effective alternative to reading raw text data. By displaying weather information using graphical indicators on a timeline stack, we have shown that the cognitive load required to interpret weather data can be dramatically reduced. Furthermore, the required time and expertise are similarly reduced. We presented three sample scenarios that demonstrate the flexibility of this approach for assisting with planning flights with different weather requirements.

Initial discussions with potential SkyScope users have resulted in enthusiastic responses. Several of these users indicated that they would like this system to be made available online. We believe that SkyScope represents a promising new way of visualizing aviation weather data. Furthermore, it seems likely that in the future pilots will regularly make use of tools based on the concepts introduced by SkyScope.

References

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[3] GTAF program http://wiis.tu-graz.ac.at/en/gtaf.html.

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