Aviation Weather Reports and Forecasting

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Aspire to the highest levels of technical proficiency as it relates to flight operations and engineering processes. (EU5)

Develop an uncompromising safety mindset, understanding that growth and development in the aviation/aerospace industry must always be accompanied by responsive safety initiatives. (EU6)

ESSENTIAL QUESTIONS

1. Why is weather forecasting important to aviation safety?
2. What weather information does a pilot have access to before and during a flight?
3. What factors related to weather must a pilot consider to make a competent go/no-go decision for flight?

LEARNING GOALS

Students Will Know

- The role that government weather forecasting and reporting play in aviation safety
- Technologies employed by the government to support aviation forecasting and reporting
- How to read a common aviation forecast

Students Will Be Able To

- *Describe* why aviation weather reporting and forecasting are vital to aviation safety. (DOK-L2)
- *Explain* the government's role in providing aviation weather services. (DOK-L2)
- *Asses* weather reports to make go/no-go decisions for flight. (DOK-L3)

ASSESSMENT EVIDENCE

Warm-up
Have students list ways they receive weather information and how they use that information. Gauge their level of understanding regarding how important weather forecasts and observations are for aviation safety.

Formative Assessment
Students will decode a Terminal Aerodrome Forecast and think critically about whether they would fly based on the forecast weather.

Summative Assessment
Students will write position papers that will allow teachers to assess their understanding of the importance of weather reporting and forecasting to flight safety and the government's role in providing this valuable information.

LESSON PREPARATION

MATERIALS/RESOURCES

- Aviation Weather Reports and Forecasting Presentation
- Aviation Weather Reports and Forecasting Student Activity 1
- Aviation Weather Reports and Forecasting Student Activity 2
- Aviation Weather Reports and Forecasting Teacher Notes 1
- Aviation Weather Reports and Forecasting Teacher Notes 2

LESSON SUMMARY

Lesson 1: Aviation Weather Reports and Forecasting

This three-session lesson will introduce students to the importance of weather reports and forecasts for maintaining safe and efficient operation of aircraft and the government's role in providing this vital information.

Begin the lesson by asking students to relate how and why they get weather reports and forecasts. Through a class discussion, students will begin to understand how weather forecasts and observations allow us to stay out of danger and make informed decisions. To further emphasize the importance of weather forecasts and reports, teachers will show students a weather-related aviation accident video.

Students will learn about pilots' access to weather information, the services provided by National Weather Service (NWS), and several different kinds of aviation weather reports and forecasts it provides. Students will review a Terminal Aerodrome Forecast with the teacher and then practice decoding their own, considering whether they would fly given the forecast information.

The third session of the lesson will focus on some technologies and tactics that are used in aviation weather reporting and forecasting. The day will begin with a video about NOAA's Hurricane Hunters. Students then will study weather balloons, which are also used to gather weather data.

Finally, students will write position papers that will allow teachers to assess their understanding of the importance of weather reporting and forecasting to flight safety and the government's role in providing this valuable information.

BACKGROUND

Weather forecasts and observations help pilots stay out of danger and make informed decisions. Pilots use weather reports and forecasts to prevent them from being surprised and trapped by adverse weather conditions. The government's role in providing weather information to pilots is critical.

The National Weather Service's (NWS) mission is to provide forecasts, warnings, and data about weather, water, and the climate to protect life and property and to enhance the national economy. The NWS is an important government agency that is part of the National Oceanic and Atmospheric Administration (NOAA).

The NWS performs its primary task through a collection of national and regional centers, and through more than 120 local weather forecast offices (WFOs). As the NWS is a government agency, most of its products are in the public domain and available free of charge.

The term weather describes the state of the atmosphere at a given point in time and geographic location. Weather forecasts estimate the conditions we expect to experience in the near future and are based on statistical models of similar conditions from previous weather events.

Temperature, amount and form of airborne moisture, cloudiness, and strength of wind are all different components of weather. Severe weather events such as tornadoes, tropical storms, hurricanes, floods, lightning strikes, and extremes of heat or cold can be costly and deadly. Knowing how to recognize threatening weather conditions, where to get reliable information, and how to respond to this information can help save lives.

In addition to weather, the NWS and NOAA monitor and forecast other atmospheric processes that affect our planet such as ozone levels, changing climate conditions, and variables outside Earth's atmosphere, such as solar winds.

There are four types of weather observations that pilots use - surface, upper air, radar, and satellite.

Surface weather reports provide local weather conditions for a specific airport. This information could include the wind speed and direction, visibility, cloud bases, temperature and dew point readings, altimeter reading, and other weather phenomena like rain or snow.

Meteorological Aerodrome Report, commonly referred to as METARs, are surface weather observations collected from ground stations. Government and privately-contracted ground stations provide up-to-date weather information at airports across the country.

Automated weather observation systems (AWOS) and automated surface observation systems (ASOS) also play a major role in providing surface weather information to pilots.

Upper air weather observations are more difficult to make than surface observations. Weather balloons are often used by the NWS to improve weather reporting and forecasting by obtaining hard-to-get upper air observations at altitudes as high as 115,000 feet.

PIREPs, or pilot weather reports, are upper air weather observations submitted by pilots regarding current conditions such as turbulence, icing and cloud heights. As PIREPs are submitted, air traffic control adds them to a distribution system for other pilots to access.

Radar weather reports (SD) provide information on the type, intensity and location of precipitation. They may include the direction and speed of the precipitation as well as the height and base of the precipitation.

Through satellite technology, pilots are now able to access weather uplinks in flight through satellite signals providing current weather data.

Aviation forecasts are used in the pre-flight planning stage to determine time of departure/arrival, route, alternate airports, and if a safe flight is even possible. A terminal aerodrome forecast (TAF) provides a report for the five statute mile radius around an airport, is valid for a 24-hr time period, and is issued four times a day. A TAF provides the type of report, station identifier, date and time of origin, forecast time period, forecast wind, forecast visibility, forecast sky condition, forecast changing conditions, forecast probability, and forecast significant weather. This information is provided in a code to shorten the report.

The nautical mile, referenced above, is a common aviation measurement used for navigation and flight planning purposes. One nautical mile is equal to one minute of latitude and is abbreviated as nm.. A knot measures speed and is abbreviated as "kts" when used in its plural form. Statute miles, abbreviated as sm, are used to measure visibility and are used in airspace and altitudes. For the teacher's understanding, 1 nautical mile = 1.1508 statute miles, but this conversion will not be used in this lesson.

There are many additional weather reports and forecasts available to pilots. For the sake of this lesson, students will be introduced to TAFs and will learn how to read them. They will begin practicing decision making based on weather reports and forecasts. Weather theory, reports and forecasts, and the ability to make decisions based on weather, will be covered in more detail in future AOPA courses.

For more information on weather reports and forecasts, see https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/15_phak_ch13.pdf. For more information on how to read TAFs, see https://aviationweather.gov/static/help/taf-decode.php.

DIFFERENTIATION

To promote reflective thinking and guided inquiry in the **ENGAGE** section of the lesson plan, circulate around the classroom and assist students who might have trouble coming up with ideas for the Warm-Up. Ask questions that provoke their own ideas for possible answers.

Teachers may use a Think-Pair-Share approach or ask students to work in pairs or small groups to compile their answers to the AOPA Air Safety Institute accident case study video "In Too Deep" during the **EXPLORE** section.

LEARNING PLAN

ENGAGE

Teacher Material: Aviation Weather Reports and Forecasting Presentation

Slides 1-3: Introduce the topic and learning objectives for this lesson.

Slide 4: Conduct the **Warm-Up**. Remind students that observing the daily weather is part of a regular routine for many people. It helps people decide what to wear and which activities to do each day. Emphasize to students that weather forecasts and observations allow people to stay out of danger and make informed decisions. In flying, making sound decisions based on weather reports is critical to keeping pilots and passengers safe. Pilots should use weather reports and forecasts to prevent them from being surprised and trapped by adverse weather conditions.

Have students list ways they receive weather information and how they use that information. Gauge their level of understanding in how important weather forecasts and observations are for aviation safety. Ask students to individually write their response to the question. When students are finished, ask volunteers to share what they wrote with the class and allow for a brief discussion.

[DOK-L2; predict, interpret]

Warm-Up

Ask students the following questions and lead a class discussion:

1. Where do you get your weather information each day?

2. What kinds of details are included in the weather forecasts you use??

3. How do you use weather forecasts in your decision making each day?

4. Where do you think pilots obtain weather information?

Questions

Possible answers to the warm-up questions include:

1. *Students may say they get weather from looking outside, listening to the radio, looking at an app on their phones or watching television (i.e., The Weather Channel).*

2. *Precipitation predictions, cloud cover, temperature, wind, weather patterns, time precipitation is forecast to arrive, etc.*

3. *They may use forecasts to dress properly (i.e., whether to bring a rain jacket or wear snow boots.) If they have sports practice or a game, they may want to know the weather in order to ensure they have the most appropriate gear.*

4. *Government-issued reports, from other pilots, the Internet, from air traffic controllers.*

EXPLORE

Teacher Material: Aviation Weather Reports and Forecasting Presentation

Slides 5-10: Explain to students that you will show them the AOPA Air Safety Institute accident case study video "In Too Deep" after teaching them some terms related to weather. The video is about a pilot who crashed his airplane because he didn't heed all of the valuable weather information available to him.

Before showing the video, discuss four important aviation weather terms with the students. The definitions are included in the presentation.

- Instrument Meteorological Conditions
- Visual Meteorological Conditions
- Ceiling
- Visibility

Share with students that private pilots must follow visual flight rules and fly in visual meteorological conditions (VMC). Flying "VFR" means flying under a set of regulations in which a pilot operates an aircraft in which weather conditions are clear enough for the pilot to see where the aircraft is going. Instrument flight rules (IFR) are the rules followed in instrument meteorological conditions (IMC), such as when flying in clouds. Private pilots are not allowed to fly by IFR rules or in IMC conditions unless they also hold an instrument rating. But occasionally, private pilots without an instrument rating find themselves in IMC due to a change in weather, not thoroughly checking weather reports and forecasts, or feeling pressure to fly regardless of poor weather. Instrument-rated private pilots can fly in VMC or IMC conditions if desired. Instrument pilots may choose to file an instrument flight plan with air traffic control even when the weather is good.

Slide 11: Show students the video "In Too Deep." This video is an engaging account of a non-instrument-rated private pilot (he wasn't rated to fly in the clouds) who crashed his airplane because he didn't heed all the valuable weather information available to him.

- "Accident Case Study: In Too Deep" (Length 15:05)

  http://video.link/w/IyMd

Students should take notes while viewing. Impress upon the students how valuable that consistent, timely, and accurate weather information is for pilots. The U.S. government provides weather forecasts. As a government function, weather forecasts are in the public domain and available free of charge.

Ask students to consider the following questions as they watch the video.

Questions

What kind of weather information was available to the pilot before he took off?

Weather forecasts indicated an area of low pressure where he was flying, and IFR (cloudy) weather conditions were forecast along with light rain.

What kind of weather information was available to the pilot through the air traffic controllers?

The controllers provided real-time weather conditions at all the airports in the area the pilot was flying, including ceiling and visibility information. The controllers were providing all the information the pilot needed to stay out of instrument conditions and re-enter visual conditions. The controllers offered to provide vectors (like directions) to an airport with better visibility. Unfortunately, the pilot didn't heed the information or take advantage of the assistance the controllers were able to offer.

Teaching Tips

Teachers may use a Think-Pair-Share approach or ask students to work in pairs or small groups to compile their answers to the accident case study video.

EXPLAIN

Teacher Materials: Aviation Weather Reports and Forecasting Presentation, Aviation Weather Reports and Forecasting Teacher Notes 1
Student Material: Aviation Weather Reports and Forecasting Student Activity 1

Slides 12-14: Lead the class through a discussion about pilot access to weather information, the services provided by NOAA and the NWS, and some of the different kinds of aviation weather reports and forecasts they provide.

The NWS performs its primary task through a collection of national and regional centers, and more than 120 local weather forecast offices (WFOs). Because the NWS is a government agency, most of its products are in the public domain and available free of charge. NOAA is part of NWS.

The term weather describes the state of the atmosphere at a given point in time and geographic location. Weather forecasts provide an estimate of the conditions we expect to experience in the near future and are based on statistical models of similar conditions from previous weather events.

Temperature, amount and form of airborne moisture, cloudiness, and wind strength and direction are all different components of our weather. Severe weather events such as tornadoes, tropical storms, hurricanes, floods, lightning strikes, and extremes of heat or cold can be costly and deadly. Knowing how to recognize threatening weather conditions, where to get reliable information, and how to respond to this information can help save lives.

In addition to weather, the NWS/NOAA also monitors and forecasts other atmospheric processes that affect our planet such as ozone levels, changing climate conditions, and variables outside Earth's atmosphere such as solar winds.

Slide 15: To begin the second session of this lesson, introduce students to Terminal Aerodrome Forecasts (TAFs).

Each area's weather forecast office (WFO) has responsibility for the issuance of Terminal Aerodrome Forecasts (TAFs) for airports in its jurisdiction. TAFs are concise, coded 24-hour or 30-hour forecasts for a specific airport that are issued four times per day (or every 6 hours) with amendments as needed. Unlike a weather forecast you might see on the news, a TAF only addresses weather elements critical to aviation; these include wind, visibility, and ceiling. Pilots use these forecasts to plan their flights and assess if they are able to fly to their destination safely or not.

Slide 16: This slide provides an outline for the information that is provided in a TAF report. Before teaching the content on the next slide, provide students with **Aviation Weather Reports and Forecasting Student Activity 1.** Ask the students to use https://aviationweather.gov/taf/decoder or other Internet sources to complete the first page of the activity with a partner. After students have completed the first page, review the answers as a class.

Slides 17-20: Use these slides to help students begin to read and interpret TAF reports using what they learned on page one. Slides 17-20 are the first two example TAFs provided on **Aviation Weather Reports and Forecasting Student Activity 1**. Slide 17 provides an explanation for the coding at the top of the TAF image and Slide 18 provides a thorough explanation for the top line in green font. This line correlates with the text provided immediately below "8:00 a.m. EDT (Current)," but is just a different representation of the same information. Ask students to discuss whether or not they would fly based on this information provided to them in the TAF. Students should recognize that clouds are high, winds are pretty light, and there seems to be good visibility. There also does not appear to be any precipitation in the area. They should make the determination that they should go fly.

Ask students to work in pairs to review the TAF for Duluth International Airport, also on **Aviation Weather Reports and Forecasting Student Activity 1.** After students decipher the weather information, they should consider whether they would go fly based on the forecast that was provided. If there is time, have a class discussion and ask students to use evidence provided in the TAF for the basis of their decision. The TAF is decoded on Slide 20. Answers are provided in **Aviation Weather Reports and Forecasting Teacher Notes 1.**

Slide 21: Conduct the Formative Assessment. Have students decode the two remaining Terminal Aerodrome Forecasts in **Aviation Weather Reports and Forecasting Student Activity 1.** Ask them to think critically about whether they would fly based on the forecast weather. Answers are provided in **Aviation Weather Reports and Forecasting Teacher Notes 1.** This assessment will conclude the second session.

[DOK–L2; classify, interpret]

Teaching Tips

For the sake of time, teachers may assign the formative assessment as homework.

EXTEND

Teacher Materials: Aviation Weather Reports and Forecasting Presentation, Aviation Weather Reports and Forecasting Teacher Notes 2
Student Material: Aviation Weather Reports and Forecasting Student Activity 2

Slide 22: The federal government uses aviation as a tool to gather weather information. As an example, NOAA's "Hurricane Hunters" fly specially equipped aircraft that play an integral role in hurricane forecasting. Data collected during these missions help forecasters make accurate predictions during a hurricane and help hurricane researchers better understand storm processes, thereby improving forecast models.

In addition, the crews conduct various research projects, including ocean wind studies, winter storm research, thunderstorm research, coastal erosion research, and air chemistry flights.

Slide 23: NOAA operates two Lockheed WP-3D Orions, nicknamed "Kermit" and and "Miss Piggy."

These aircraft conduct low-altitude data collection to fill gaps in data not available from ground-based radar or satellite imagery. The aircraft are equipped with an array of scientific instrumentation, radars, and recording systems for measurements of the atmosphere, the earth, and its environment.

To obtain the best possible data within the storm environment, crewmembers deploy expendable probes called GPS "dropwindsondes" through a launch tube in the aircraft. As they parachute to the sea below, the probes transmit pressure, temperature, humidity, wind speed, and wind direction data back to the aircraft. The Doppler shifts are used to compute the horizontal and vertical wind components.

NOAA's WP-3D Orions are also equipped with Doppler radar. The radar is mounted to the belly of the aircraft. When the aircraft is flown through a storm, meteorologists use the radar to scan the storm both vertically and horizontally. This reveals the different layers and the internal structure of the storm. The radar images allow forecasters and researchers to improve forecasting capabilities.

Slide 24: NOAA also has a specially equipped Gulfstream IV-SP, nicknamed "Gonzo."

Its primary mission is to fly tropical cyclone surveillance missions. It has an ability to fly up to 4,000 miles and cruise at an altitude of 45,000 feet, which allows it to provide observational coverage at high altitudes, which is critical for defining weather systems in the upper atmosphere.

Like "Miss Piggy" and "Kermit," "Gonzo" has the ability to drop GPS "dropwindsondes." The dropsonde is released from the aircraft. It measures and transmits back to the aircraft the pressure, temperature, humidity, and GPS Doppler frequency shifts as it descends to earth. The Doppler shifts are used to compute the horizontal and vertical wind components.

It also has a Doppler radar that can look at the structure of a storm to help determine its intensity. The radar scans the storm both vertically and horizontally, allowing forecasters and researchers to see the different layers of a storm, which helps improve forecasting capabilities.

Slide 25: Show this video to provide students with an overview of the process used by NOAA's Hurricane Hunters. Advise students to pay close attention to the following questions. At the conclusion of the video, lead a class discussion and allow students to answer these questions.

- Flying through a Hurricane Eye Wall" (Length 4:16)

http://video.link/w/JyMd

Questions

What information do the scientists gather by flying into the hurricanes?

Possible Answers: Data that indicates where the storm is going by pinpointing the center of the hurricane or data that indicates how strong the storm is by collecting radar information, wind direction, and strength.

What safety measures must be taken to penetrate the wall of the storm?

Possible answers: All people and equipment are strapped down and carefully secured and pilots must manage the engine and the aircraft speed carefully. This is indicated by the third pilot carefully managing the airplane's thrust levers.

Teaching Tips

As an optional approach, teachers may ask students to work in pairs or small groups to compile their answers.

Slide 26: Ask students if they would want to fly one of NOAA's specially-equipped hurricane hunting airplanes. Perhaps they would prefer to be a scientist gathering data or managing a system located in the back of the aircraft.

Slide 27: Provide a career spotlight on NOAA crew members. For more information, visit https://www.omao.noaa.gov/connect/faq/what-does-it-mean-be-noaa-corps-officer

Slides 28-29: Allow students to study one additional technology used to gather weather data through aviation: weather balloons.

Provide students **Aviation Weather Reports and Forecasting Student Activity 2**, where they will research weather balloons. The NWS uses balloons to improve weather reporting and forecasting by obtaining hard-to-get upper air observations. Using the Internet, students will answer the questions on the graphic organizer. When they are finished, students should pair up and check their answers with a classmate. Teachers can find answers in **Aviation Weather Reports and Forecasting Teacher Notes 2.**

Prior to completing the activity, show students a video of a weather balloon launch.

- "Special Weather Balloon Launch" (Length 1:04)

  http://video.link/w/MyMd

EVALUATE

Teacher Material: Aviation Weather Reports and Forecasting Presentation

Slide 30: Conduct the **Summative Assessment.**

Students will write position papers that will allow teachers to assess their understanding of the importance of weather reporting and forecasting to flight safety and the government's role in providing this valuable information.

Summative Assessment

Ask students to write at least three paragraphs in response to the following questions:

- *How important are weather reports and forecasts to flight safety?*
- *Who should perform this function, and why?*

Summative Assessment Scoring Rubric

Follows assignment instructions and submits work that is neat and organized.

Paper shows evidence of one or more of the following:

- An understanding of the importance of weather reports and forecasts which enable pilots to make informed decisions regarding weather and flight safety before and during a flight.
- An understanding of technologies used for forecasting and reporting.
- An understanding of the government's role in providing critical weather information and forecasts.

Paper shows an understanding of course of the concepts covered in the lesson.

Paper shows an in-depth thinking including analysis or synthesis of lesson objectives.

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

GOING FURTHER

Show students the "STEM Stories" video about the career of a NOAA research meteorologist (Length 4:31): http://video.link/w/PyMd

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-ETS1-3 -** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - Influence of Science, Engineering, and Technology on Society and the Natural World
- **HS-ETS1-4** - Use a computer simulation to model the impact of proposed solutions to a complex realworld problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
    - Science and Engineering Practices
        - Using Mathematical and Computational Thinking
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - Systems and System Models

COMMON CORE STATE STANDARDS

- **HSN-Q.A.2-3** - Reason quantitatively and use units to solve problems.
- **HSS-ID.B.5** - Summarize, represent, and interpret data on two categorical and quantitative variables.
- **RST.9-10.1** - Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

- **RST.9-10.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.
- **WHST.9-10.2** - Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- **WHST.9-10.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.

REFERENCES

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