Probabilistic Turbulence Forecast Research Results

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Presented By: AWDE Services
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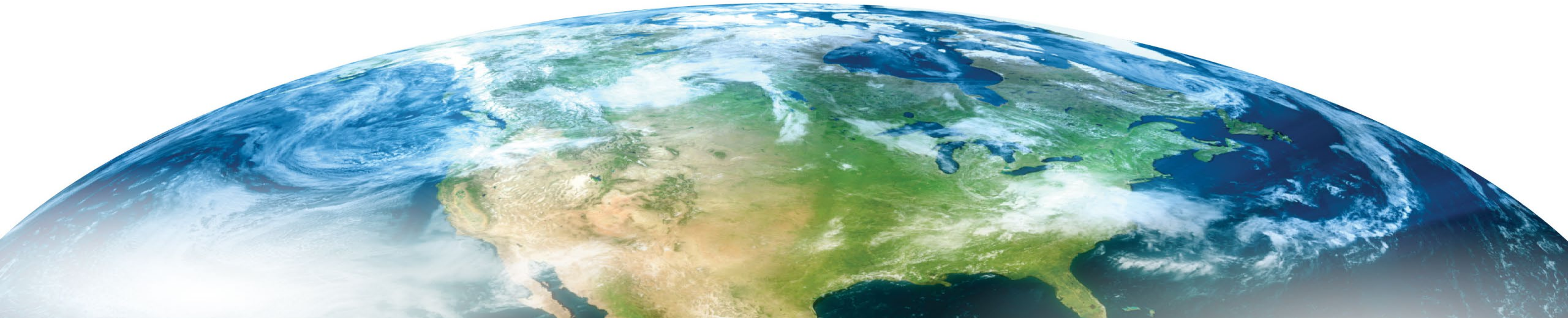

Topics

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Introduction

Introduction

- The Weather Research Branch, ANG-C61, is collaborating with the University Corporation for Atmospheric Research (UCAR), to aid in developing probabilistic turbulence forecast products.
- Aviation Weather Demonstration and Evaluation (AWDE) Services program at the Federal Aviation Administration (FAA) William J. Hughes Technical Center (WJHTC) has been tasked to determine how users may use and interpret a probabilistic forecast and what information is needed in a probabilistic turbulence forecast.

Background and Objectives

Background

- Forecasting products are evolving and the technology and science improvements to these products are providing a more extended range forecast.
- As more detailed forecast information becomes available, the methods used for presenting and interpreting information must progress.
- The advancements in technology and information available are making probabilistic forecasting more readily available to the users and provide more information.
- Probabilistic forecasts allow users to evaluate several forecast outcomes at one time.
- Current turbulence products use deterministic forecasts which provide a single-value forecast.
- Currently, there are no probabilistic turbulence forecast products being used operationally.

Objectives

- Determine how users could utilize and interpret a probabilistic turbulence forecast.
- Determine what information is needed in a probabilistic turbulence forecast to support operational decision-making.

Approach

Focus Group Participants

- Participants
  - A total of forty participants were interviewed as part of focus groups either in person or via WebEx teleconference.

- User group categories:
  - Part 121 pilots.
  - General Aviation (GA) pilots.
  - Weather Forecast Office (WFO) meteorologists.
  - Airline Operations Center (AOC) dispatchers.
  - Airline Operations Center (AOC) meteorologists.
  - Helicopter Emergency Medical Services (HEMS) pilot.
  - Center Weather Service Units (CWSU) meteorologists.
  - National Oceanic and Atmospheric Administration (NOAA) meteorologists.

Participants and Locations

- August 19th – 23rd WJHTC Atlantic City, NJ
  - 9 GA Pilots
- August 19th – 23rd Aviation Weather Center (AWC) Kansas City, MO
  - 3 GA pilots
  - 4 CWSU meteorologists
  - 2 WFO meteorologists
  - 2 NOAA meteorologists
  - 1 AOC meteorologist
  - 1 HEMS pilot
- September 19th WebEx hosted at the WJHTC
  - 2 AOC meteorologists
  - 1 Part 121 pilot
- October 29th Airline Operations Center (AOC)
  - 3 AOC dispatchers
  - 1 Part 121 pilots
  - 1 AOC meteorologist
- October 30th Airline Operations Center (AOC)
  - 3 AOC dispatchers
  - 1 Part 121 pilot
- November 18th WebEx hosted at the WJHTC
  - 6 AOC dispatchers

Approach

- The probabilistic turbulence research consisted of two parts:
  - Literature review and
  - Focus group sessions.
- The literature review identified:
  - There are no operational probabilistic turbulence forecast products and
  - Design strategies to display a probabilistic turbulence forecast.
- Based on the data gathered from the literature review and discussions with the FAA turbulence lead and UCAR, the AWDE Team developed mock-up Graphical User Interfaces (GUIs) demonstrating various ways to display a probabilistic turbulence forecast.
- The mock-up GUIs were presented to participants during focus group sessions.
- During the focus group sessions participants provided feedback to aid in determining how the forecasts are interpreted and the type of information needed in a probabilistic turbulence forecast display.

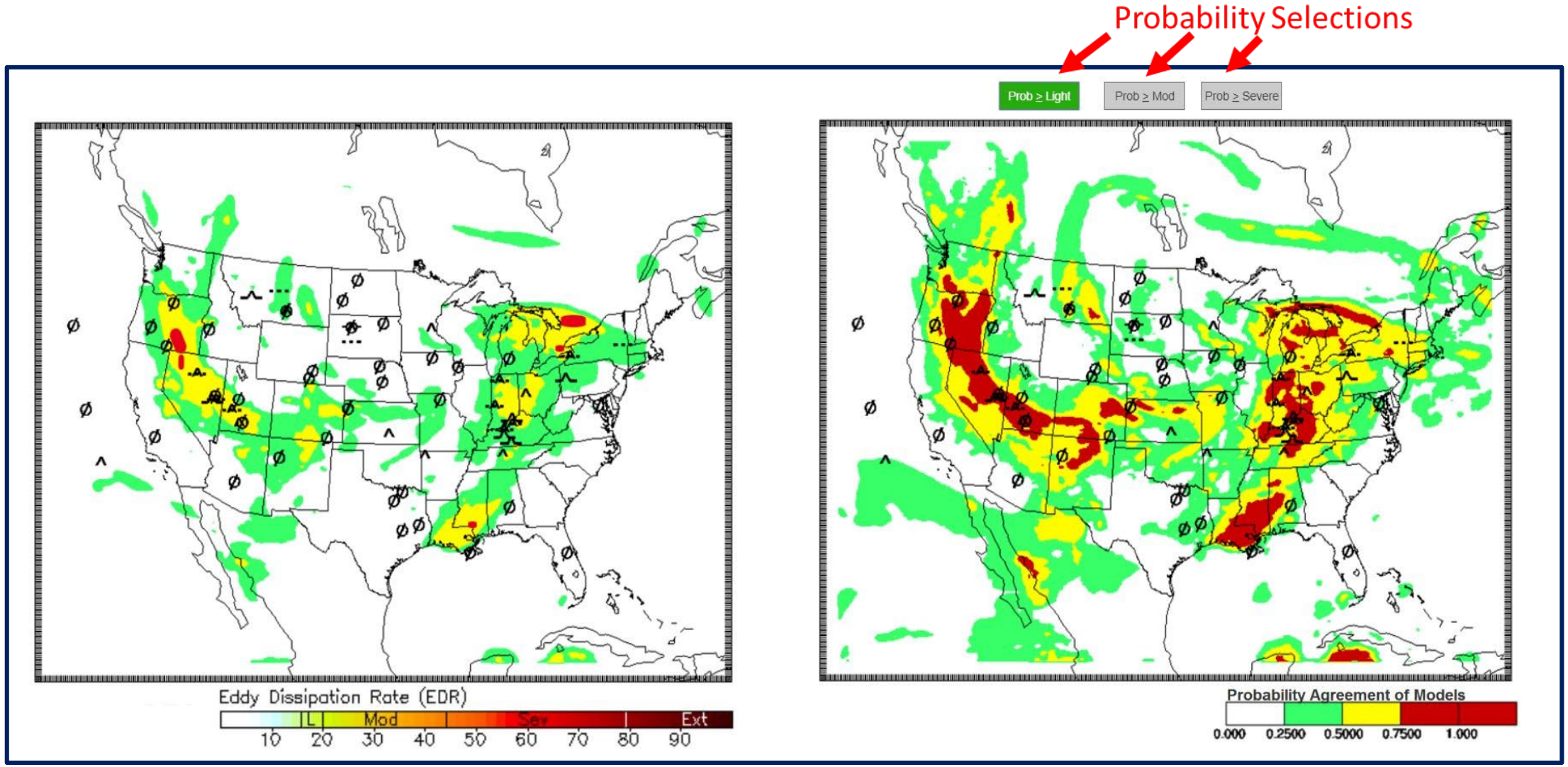
Literature Review Approach

- The focus of the literature review was to:
  - Identify current probabilistic turbulence forecast products used operationally.
  - Identify the information presented in current probabilistic turbulence forecast products.
  - Determine benefits and issues with current probabilistic turbulence forecast products.
- Various key word strings were used, such as “multiple data display and turbulence” and “ probabilistic turbulence display” to conduct searches on the internet and several databases.
- The databases used were:
  - Aerospace Research Central,
  - EBSCO Host, and
  - Pro Quest.

Probabilistic Mock-up GUIs

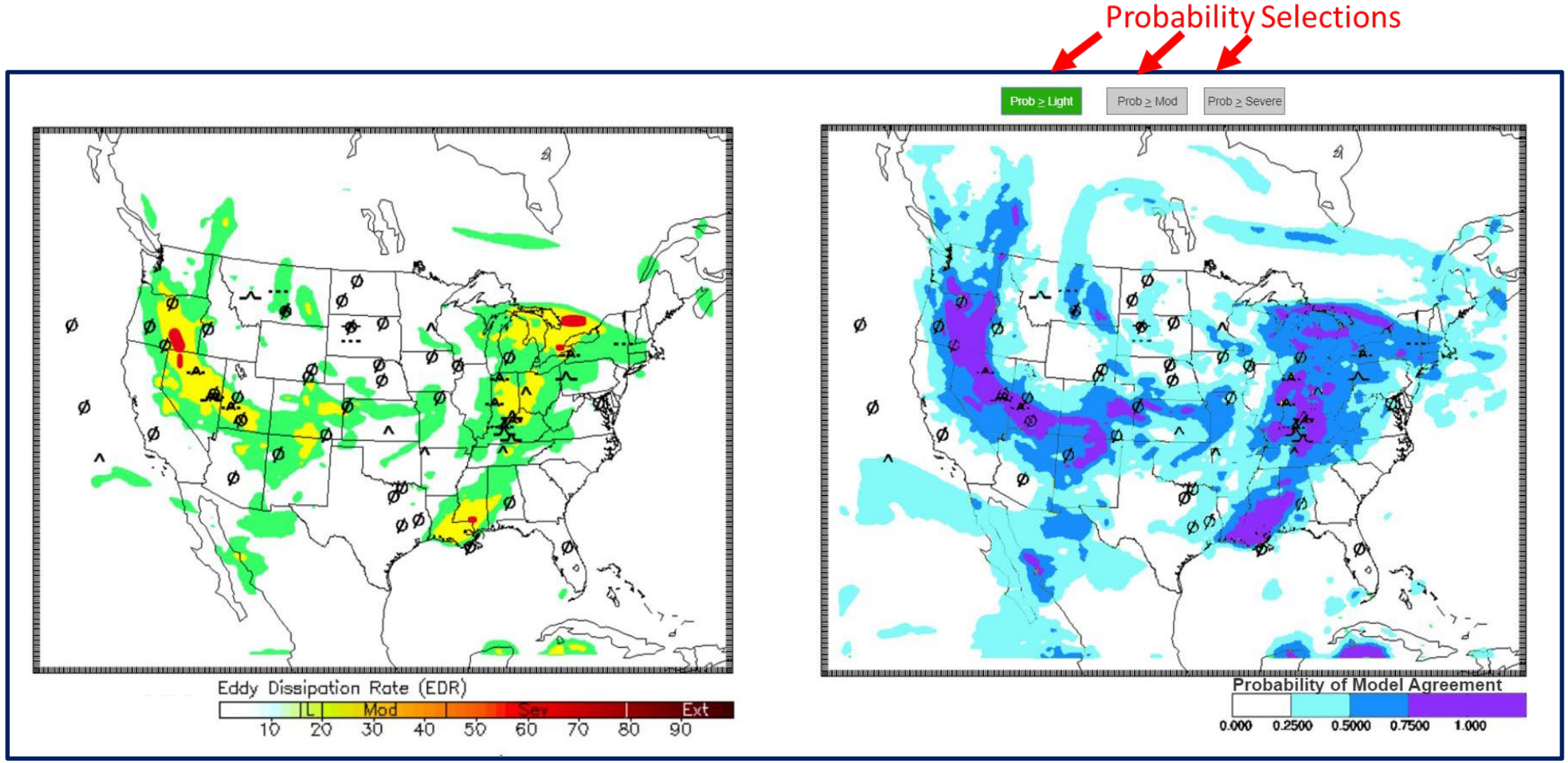
- Information gathered during the literature review provided the requirements to develop five mock-up GUIs of probabilistic turbulence forecasts.
- The five probabilistic turbulence forecast mock-up GUIs are described below:
  1. The deterministic and probabilistic forecasts were displayed side-by-side (Dual View), using the same color palette (white, green, yellow, and red).
  2. The deterministic and probabilistic forecasts were displayed side-by-side (Dual View). The deterministic forecast was presented using white, green, yellow, and red and the probabilistic forecast was displayed using variations of blue and purple.
  3. The probabilistic turbulence forecast was presented using a threshold filter (10-100%) providing the capability to select a percentage of model agreement.
  4. The probabilistic forecast was presented as a single view product using white, green, yellow, and red colors to represent probabilities.
  5. The probabilistic forecast was presented as a single view product using variations of blue and purple colors to represent probabilities

Dual View with Same Colors



Deterministic (left) and Probabilistic (right) Turbulence Forecasts.

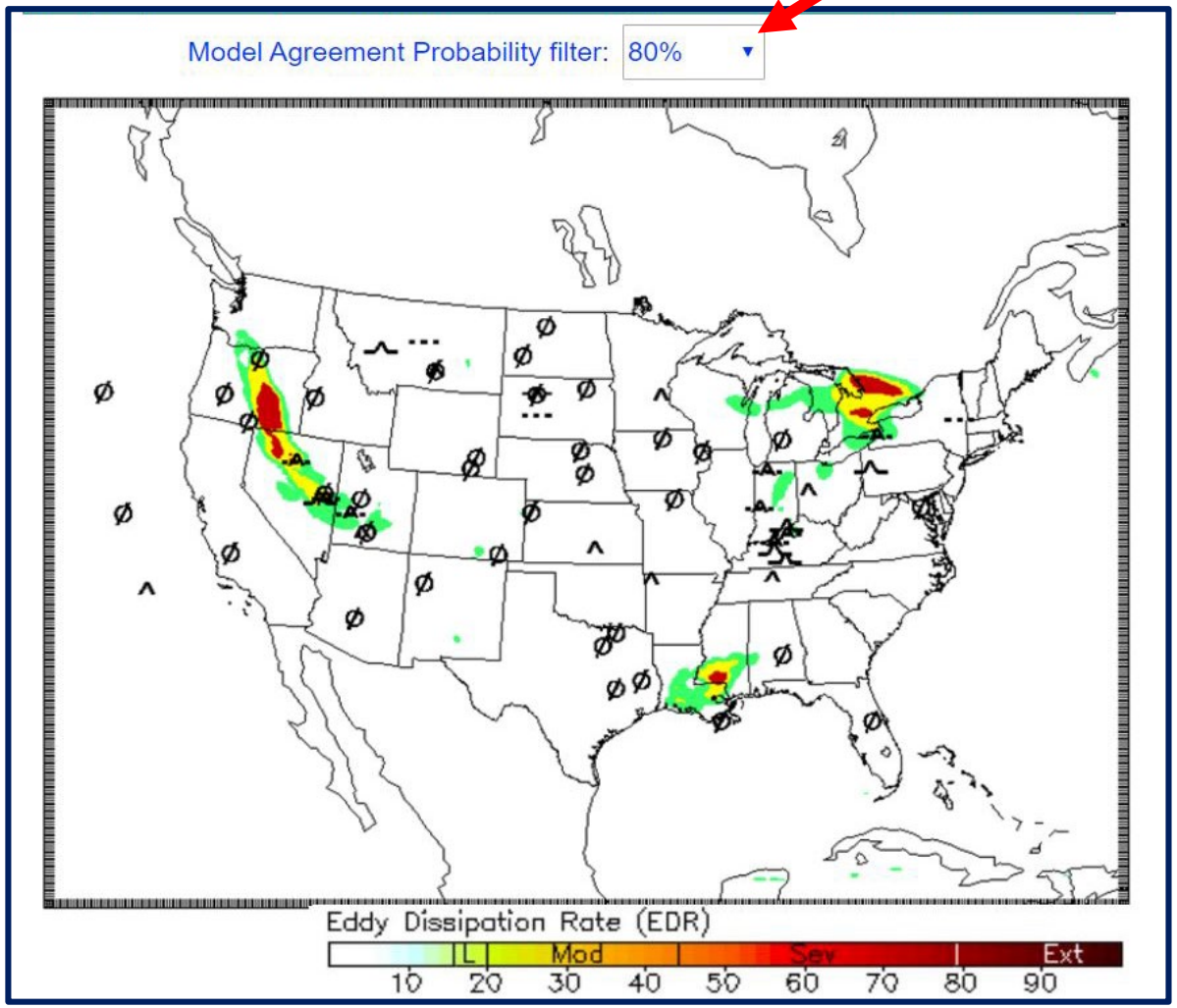
Dual View using Different Colors



Deterministic (left) and Probabilistic (right) Turbulence Forecasts.

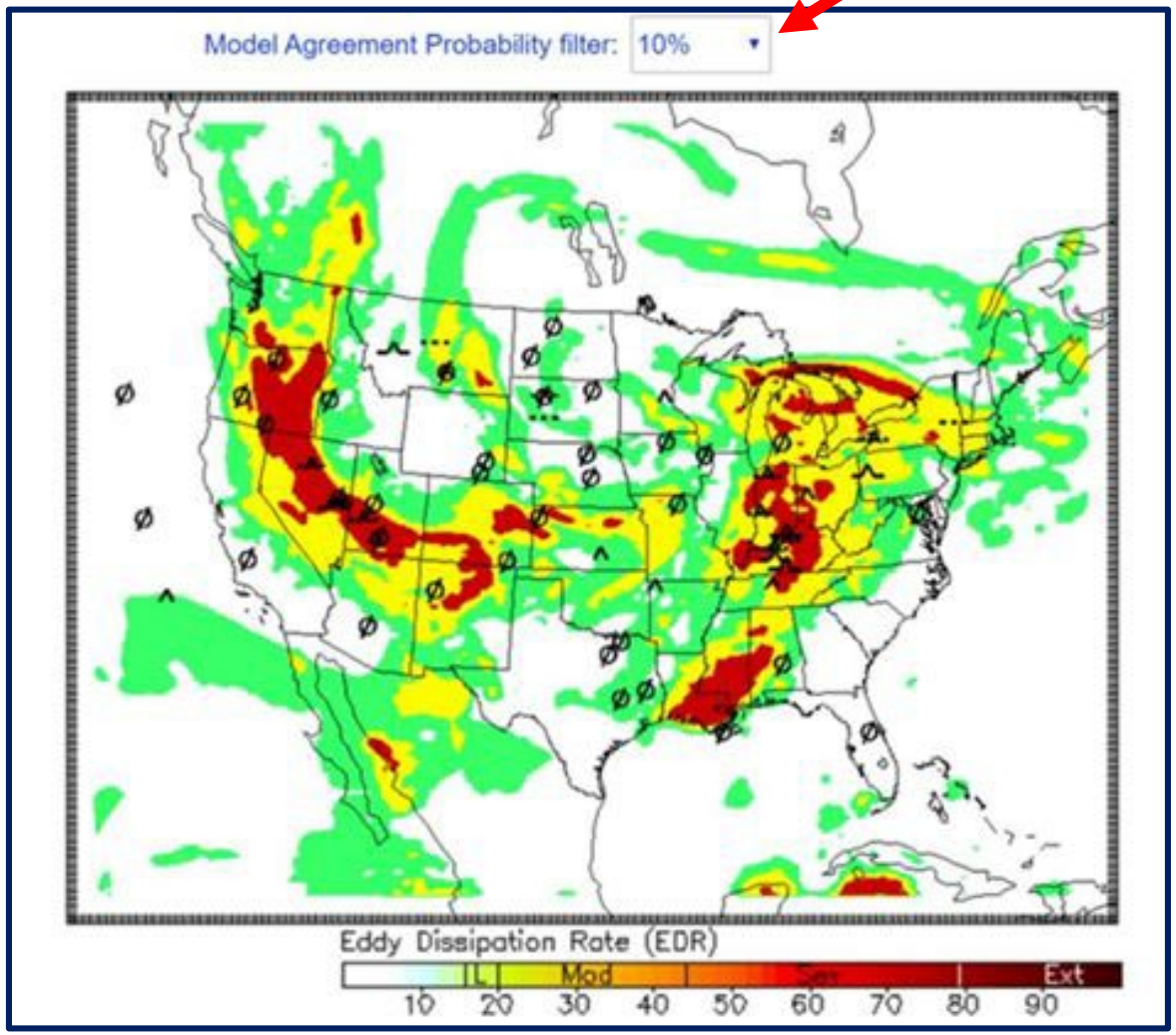
Probability Filter

Probabilistic Filter



Probabilistic filter at 80%

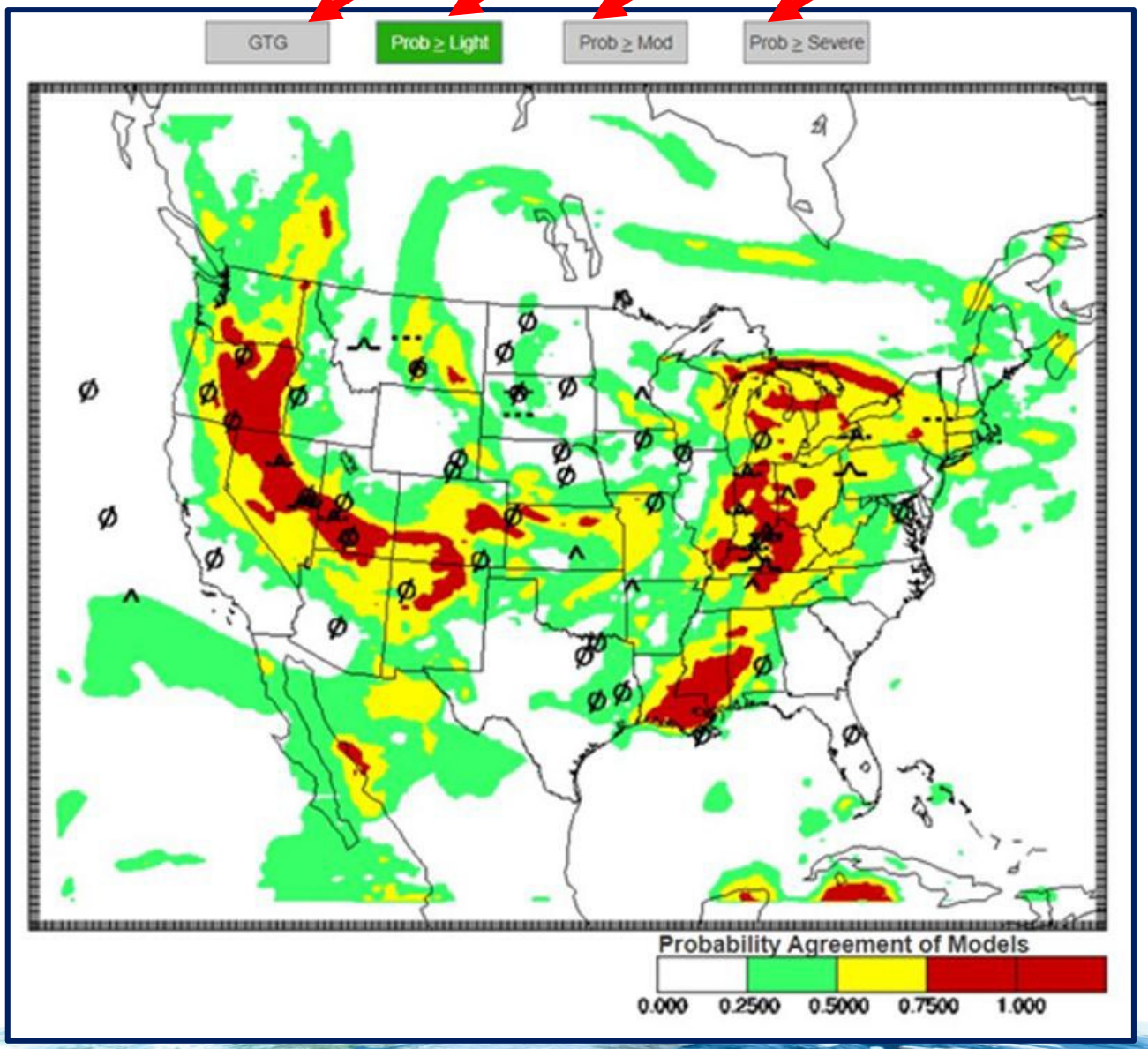
Probabilistic Filter



Probabilistic filter at 10%

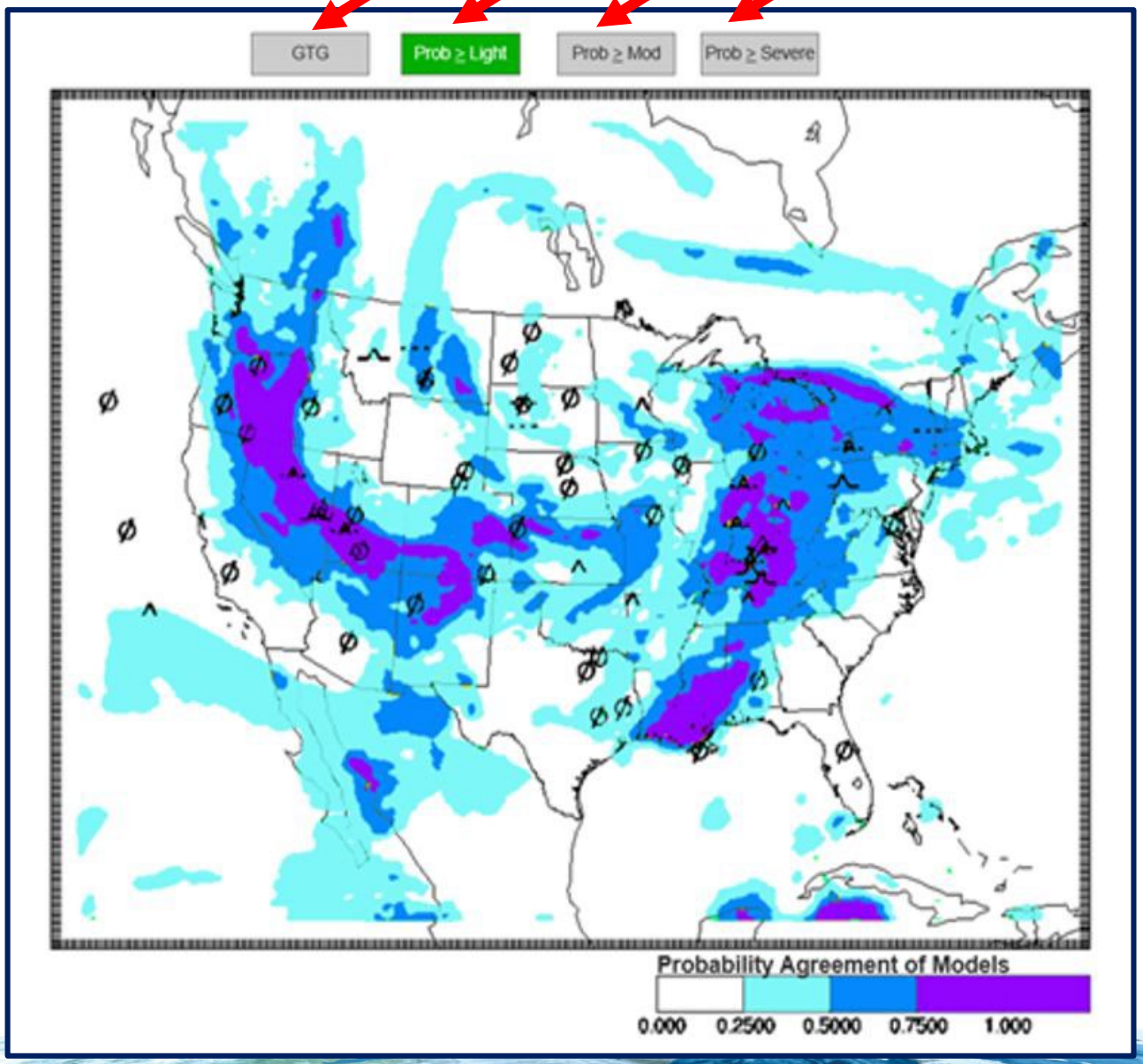
Single View using Same Colors

GTG deterministic and probability selections



Single View using Different Colors

GTG deterministic and probability selections



Focus Group Approach

- Focus groups were conducted with multiple participants in attendance.
- Each focus group session consisted of:
  - The AWDE Team providing a description of a probabilistic turbulence forecast, project goals, and participant expectations.
  - The AWDE Team providing a detailed description of the probabilistic turbulence mock-up GUIs detailing the forecast presentation, available information, capabilities, terminology, and color schemes.
  - Participants were told the mock-up GUIs were examples and not intended to be a final product, the goal of the mock-up GUIs was to provide a framework to leverage so participants could get in the mindset to think of a probabilistic turbulence forecast and how a probabilistic turbulence forecast could be presented.
  - Participants viewed the five probabilistic turbulence mock-up GUIs. The presentation order of the mock-up GUIs was counterbalanced to minimize order effect. For example, focus group 1 viewed the dual-view mock-up GUI first while focus group 2 viewed the single view mock-up GUI first.

Focus Group Approach

- Focus group participants were asked to determine if a probabilistic turbulence forecast would be used in an operational environment.
- Structured interview questions focused on gathering the following information:
  - Would a probabilistic turbulence forecast be used in an operational environment?
  - Would a probabilistic and deterministic forecast be used simultaneously?
  - What information is needed in a probabilistic turbulence forecast?
  - What configuration settings are needed when using a probabilistic turbulence forecast?
- At the end of each focus group session, participants were asked to complete a questionnaire.
  - 5-point Likert scale rating was used (5-Strongly Agree, 4-Agree, 3-Neither Agree/Disagree, 2-Disagree, and 1-Strongly Disagree).
  - Space for additional comments was provided.

Results

*Structured Interview Questions

Note: Due to time constraints not all questions were asked during each Focus Group session, therefore, feedback for all questions may be incomplete for each user group.

Question 1

1. Before today, were you familiar with the term Eddy Dissipation Rate (EDR*)?
   - All Part 121 pilots, CWSU, WFO and AOC meteorologist participants stated familiarity with the EDR term.
   - Nine out of twelve GA pilots were not familiar with the EDR term.
   - Two out of four NOAA meteorologists were familiar with the EDR term.
   - Two out of five AOC dispatchers were familiar with the EDR term.
   - The HEMS pilot was not familiar with the EDR term.

*EDR is an objective, aircraft-dependent, universal measure of turbulence based on the rate at which energy dissipates in the atmosphere.

Question 2

2. Have you used the GTG Turbulence product? If so, how often?
   - GA pilots, HEMS pilot, and WFO meteorologist participants had not used the GTG Turbulence product.
   - GA pilots do not use turbulence forecast products to aid in decision-making. GA Pilots tend to rely on precipitation and ceiling and visibility (C&V) for operational decision-making.
   - All Part 121 pilot participants use GTG Turbulence as an advisory product to inform decision-making on safe routes and altitudes.
   - All AOC dispatcher participants use the GTG Turbulence product daily to aid in determining critical turbulence information to issue for flight safety.
   - Three CWSUs, one out of two NOAA, and three out of four AOC meteorologists use the GTG Turbulence product to aid in determining forecast conditions.

Question 3

2. Describe what you would expect in a probabilistic turbulence forecast. Would you prefer the turbulence strength to be reported by EDR value (aircraft in dependent) or by strength (i.e. light, moderate, severe (aircraft dependent?)

The feedback for Question #3 was gathered through Questions #9 and 13.

Question 4

4. How would you interpret a 20% chance of moderate turbulence over a region? Participants were given the following interpretations:

   20% of the time there will be moderate turbulence over the entire region or

   20% of the region will experience moderate turbulence but 80% will not?

User Group	20% of the time there will be moderate turbulence over the entire region.	20% of the region will experience moderate turbulence but 80% will not.	Comments
GA pilots (n=12)	5		7 pilots were not clear on how to interpret the forecast, therefore, did not provide answers.
Part 121 pilots (n=3)	1	2	
CWSU meteorologists (n=4)	2	2	
WFO meteorologists (n=2)	1	1	
AOC meteorologists (n=4)	2	2	
AOC dispatchers (n=12)	7	3	2 AOC dispatchers did not provide answers.

Question 5

5. Would you use a probabilistic turbulence forecast?
   - GA pilots who only fly visual flight rule (VFR) do not use turbulence forecasts for decision-making purposes. GA pilots relay on identifying precipitation and C&V forecasts for decision-making. Turbulence is inferred using the precipitation and C&V forecast. Overall, if weather exists, the pilots will not fly.
   - GA pilots who are instrument flight rule (IFR) rated, understood the benefits of a probabilistic turbulence forecast. However, overall, turbulence still is not a factor to consider for decision-making.
   - GA pilots stated a turbulence product might be used if passengers were onboard. However, the information needed is turbulence severity.
   - CWSU, AOC, NOAA, and WFO meteorologists would use a probabilistic forecast to aid in determining the probabilities of moderate to severe turbulence to occur.
   - Part 121 pilots would use a probabilistic turbulence forecast to aid in making decisions about safer routes and altitudes to fly.
   - AOC dispatcher participants would use a probabilistic turbulence forecast to aid in determining critical turbulence information to issue for flight safety.

Questions 6 and 7

6. Is it easy to interpret a turbulence forecast? Why or why not?
   - VFR GA pilots had difficulty interpreting a probabilistic turbulence forecast. VFR GA pilots stated that the probabilistic forecast provided too much information and did not give a clear “yes” or “no” answer concerning turbulence.
   - IFR GA pilots found the probabilistic turbulence forecast somewhat easier to use than VFR GA pilots. The IFR GA pilots stated a need to become familiar with the data and to use the probabilistic and deterministic forecasts together.
   - Part 121 pilots, AOC dispatchers, AOC, CWSU, WFO, and NOAA meteorologist participants stated turbulence forecasts are easy to interpret however the probabilities must be clearly defined.
7. Would you use a deterministic and a probabilistic turbulence forecast simultaneously for decision-making?
   - In general, GA pilots do not use turbulence forecasts, however, if a turbulence forecast was used, VFR pilots only would view the deterministic forecast, while IFR pilots would use both the deterministic and probabilistic forecasts.
   - Part 121 pilots, AOC dispatchers, AOC, CWSU, WFO, and NOAA meteorologist participants would use the deterministic and probabilistic forecasts simultaneously.

Question 8

8. What probability/threshold for EDR/light, moderate and severe turbulence would cause you to modify a route?
   - For all pilot participants, light turbulence is not an issue, therefore rerouting or changing altitudes will not occur due to light turbulence.
   - GA pilots, Part 121 pilots, and AOC dispatcher participants would begin the process of rerouting with mid-range probabilities for moderate turbulence and start the process with a low probability for severe turbulence.
   - Part 121 pilots and AOC dispatchers stated rerouting, due to turbulence, is dependent upon the phase of flight and severity and duration of the turbulence.

Question 9 and 10

9. How would you prefer the probability data to be displayed (33.3%, 0.33, or as 5 out of 15)?
   - All participants prefer the probabilities to be displayed as a percentage.
   - All participants stated a need to have clear definitions of the percentage values to enable easier decision-making strategies based on the values.
10. When viewing a probabilistic turbulence forecast, is it valuable to see the separate probability for each EDR/severity level?
   - All participants stated the need to have the capability to see a probability for each of the three severities (light, moderate, and severe). This capability would provide an easy quick glance interpretation of the likelihood of the turbulence occurring.

Question 11

11. Would you want the ability to turn on/off different data sets used to develop the probabilistic turbulence forecast?
    - GA and Part 121 pilots, and AOC dispatchers do NOT want the capability to turn on/off the different data sets. Participants were not clear as to why data sets would be toggled on/off. The pilots and dispatchers do not have the expertise in the models to determine which data sets are more accurate and/or reliable.
    - The AOC, CWSU, and NOAA meteorologists stated the ability to toggle on/off data sets should be based on the user group and expertise. For example, pilots should not have the capability due to inexperience in understanding the models, whereas meteorologists should have the capability to toggle on/off data sets due to expertise in understanding the reliability and validity of the models.

Question 12

12. When using a probabilistic turbulence forecast, what is the optimal color-coding scheme or preference?
    - GA pilots, CWSU, and NOAA meteorologists preferred the color scheme representing probability to be different than the GTG turbulence severity colors.
    - Part 121 pilots stated using several shades of the same color to blend each percentage for the probabilistic turbulence forecast. One pilot stated using shades of orange would be optimal.
    - WFO meteorologists:
        - 1 out of 2 preferred using the same colors as GTG turbulence severity.
        - 1 out of 2 preferred using a different color scheme than GTG turbulence because red/yellow/green indicates severity.
    - AOC meteorologists:
        - 1 out of 3 preferred using the same color scheme as GTG turbulence severity.
        - 1 out out of 3 preferred using several shades of the same color to blend each percentage for the probabilistic turbulence forecast.
        - 1 out of 3 suggested evaluating other color possibilities to represent each percentage for the probabilistic turbulence forecast.

Question 12 Continued

12. When using a probabilistic turbulence forecast, what is the optimal color-coding scheme or preference?
    - AOC dispatchers preferred using various shades of orange to represent each percentage of the probabilistic turbulence forecast.

Question 13

13. What is your preferred wording when describing the probabilistic turbulence forecast (light moderate, severe; EDR value; isolated, frequent; percentage number)?

- GA and Part 121 pilots, AOC dispatchers, CWSU, WFO, AOC, and NOAA meteorologist participants preferred using the wording “low, medium, and high” for turbulence probability and “light, moderate, and severe” for turbulence severity.
- The HEMS pilot, one AOC dispatcher, and one CWSU meteorologist preferred a percentage number.
- One AOC meteorologist preferred having the wording “light, moderate, and severe” for turbulence severity along with percentage numbers for probability. The preference for using the terms light, moderate, and severe would make the transition to briefing pilots easier because both use groups are using same terms to describe the forecast.

Question 14

14. How would you want a probabilistic turbulence forecast displayed (i.e. overlaying high, medium, low, EDR value)?
    - GA pilot stated turbulence products are not referenced for decision-making purposes.
        - VFR GA Pilots stated a probabilistic turbulence forecast would not be used as a decision-making product.
        - IFR GA Pilots stated, if using a probabilistic turbulence forecast product, the capability to view the probabilities for light, moderate, and severe, separately is needed.
    - Part 121 pilots, AOC, CWSU, WFO, and NOAA meteorologists, and AOC dispatchers stated the capability to view the likelihood of turbulence occurring along with the severity would be the preferred turbulence forecast presentation. This would provide the capability to view the likelihood of turbulence and the severity.

Question 15

15. Which features would you want customizable for your site (i.e. severity thresholds, information displayed (EDR vs. percentage), color scheme used)?
    - GA pilots:
        - Capability to set a probability threshold for severe turbulence for go-no-go decisions.
        - Capability to select aircraft type, turbulence has different effects on different aircraft sizes.
        - Capability to toggle on/off PIREPs and METAR overlays.
        - Capability to enter and display route and zoom into the route to view turbulence along the route.
        - Capability to display historical trends of turbulence.
        - Capability to view the jet stream and wind forecasts.
    - Part 121 pilots:
        - Capability to enter and display route and zoom into the route to view turbulence along the route.
        - Capability to select aircraft type, turbulence has different effects on different aircraft sizes.

Question 15 (continued)

15. Which features would you want customizable for your site (i.e. severity thresholds, information displayed (EDR vs. percentage), color scheme used)?
    - CWSU meteorologists:
        - Capability to download the turbulence forecasts to reprocess and further analyze the data. This would provide the capability to further understand turbulence in specific areas.
        - Ensure the colors schemes for the forecasts are standardized and provide detailed definitions.
    - WFO and NOAA meteorologists:
        - Capability to set probability thresholds for each severity level, using a standard color scheme.
        - Capability to select a probability to filter out all other turbulence forecast data.

Question 15 (continued)

15. Which features would you want customizable for your site (i.e. severity thresholds, information displayed (EDR vs. percentage), color scheme used)?
    - AOC meteorologists:
        - Capability to select aircraft type, turbulence has different effects on different aircraft sizes
        - Capability to zoom in over a route.
        - Capability to display the likelihood of turbulence occurring at each severity level.
        - Capability to overlay PIREPs, AIRMETs, and SIGMETs.
        - Capability to draw a polygon on the map providing a defined area to analyze for turbulence.
    - HEMS pilot:
        - Capability to view low altitudes for turbulence.
        - Capability to enter and display route and zoom into the route to view turbulence along the route.
    - AOC dispatchers:
        - Capability to enter and display route and zoom into the route to view turbulence along the route.
        - Capability to display the likelihood of turbulence occurring using percentages for each severity.
        - Capability to overlay PIREPs, AIRMETs, and SIGMETs.

Question 16

16. Are there other critical pieces of information that are needed in a probabilistic turbulence forecast to inform decision-making?

- GA pilots:
  - Capability to display and view the jet stream.
  - Capability to select a specific altitude.
  - Capability to select type of aircraft (small, medium, heavy).
- Part 121 pilots:
  - Capability to predict convective turbulence within 5-10 minutes.
  - Capability to view each severity separately, reducing the chance of severities overlapping one another and masking-out critical information.

Question 16 (continued)

16. Are there other critical pieces of information that are needed in a probabilistic turbulence forecast to inform decision-making?
    - CWSU meteorologists:
        - Real time EDR data to overlay on top of probability map.
        - Capability to select and view different altitudes.
    - WFO meteorologists:
        - Capability to view mountain wave and CAT turbulence separately.
    - AOC meteorologists:
        - Capability to view convective turbulence within 5-10 minutes.

Question 17

17. How often do you expect elevated EDRs and do you consider elevated EDRs to be a rare or frequent event?

Participants in each user group agreed that moderate to severe elevated levels of turbulence is a rare and infrequent event.

Questionnaire Results

Questionnaire

- Participants were asked questions about features or capabilities needed in a Probabilistic Turbulence Forecast product.
- Participants used 5-point Likert scale level of agreement rating for each question. The rating used was:
  - 5 – Strongly Agree,
  - 4 – Agree,
  - 3 – Borderline (neither agree, no disagree),
  - 2 – Disagree,
  - 1 – Strongly Disagree
- The results were analyzed calculating the median and mean.

Questionnaire Results

Question 5 – Strongly Agree, 4 – Agree, 3 – Borderline, 2 – Disagree, 1 – Strongly Disagree	GA pilots	Part 121 pilots	CWSU / AOC meteorologists	AOC dispatchers	1 HEMS pilot	WFO/NOAA meteorologists*
	Median (Mean) n					
Q1. A probabilistic turbulence forecast would be suitable for use in my operational environment.	4 (4.0) n=12	4 (4.33) n=3	4 (4.17) n=6	4 (3.67) n=3	4	5 (4.67) n=3
Q2. It is necessary to be able to toggle on/off each forecast (data set) for adequate decision-making.	4 (3.27) n=11	5 (4.67) n=3	5 (4.17) n=6	4 (3.67) n=3	5	4.5 (4.5) n=4

**Note: WFO/NOAA meteorologists do not use turbulence products for decision-making purposes.*

Questionnaire Results

Question 5 – Strongly Agree, 4 – Agree, 3 – Borderline, 2 – Disagree, 1 – Strongly Disagree	GA pilots	Part 121 pilots	CWSU / AOC meteorologists	AOC dispatchers	1 HEMS pilot	WFO/NOAA meteorologists*
	Median (Mean) n					
Q3. The ability to select a turbulence threshold (e.g. moderate turbulence 40% or greater) would aid in flight planning.	4 (4.17) n=12	5 (4.67) n=3	4 (4.25) n=6	4 (4.3) n=3	4	5 (4.75) n=4
Q4. The ability to set customized features such as thresholds would be useful in my operational environment.	4 (3.75) n=12	4 (4.0) n=3	4 (4.0) n=6	2 (2.67) n=3	5	5 (4.33) n=3

Q4. AOC dispatchers Disagreed that having the ability to set a threshold would be useful in an operational environment. This is because AOC dispatchers do not need the capability to **set** customized features, the need is only to select and view turbulence threshold values. Threshold values would be set by the AOC meteorologists.

**Note: WFO/NOAA meteorologists do not use turbulence products for decision-making purposes.*

Questionnaire Results

Question 5 – Strongly Agree, 4 – Agree, 3 – Borderline, 2 – Disagree, 1 – Strongly Disagree	GA pilots	Part 121 pilots	CWSU / AOC meteorologists	AOC dispatchers	1 HEMS pilot	WFO/NOAA meteorologists*
	Median (Mean) n					
Q5. A probabilistic turbulence display would provide better information than a deterministic display for decision-making capabilities.	3 (3.17) n=12	3 (3.67) n=3	4.0 (3.67) n=6	3 (3.3) n=3	3	4 (3.75) n=4

GA pilots, Part 121 pilots, AOC dispatchers, and the HEMS pilot were Borderline on rating if a probabilistic turbulence display would provide better information than a deterministic display for decision-making. This is because the user groups rely heavily on severity information. Viewing a probability turbulence forecast alone, would not provide better information and would not be used as a stand-alone product.

**Note: WFO/NOAA meteorologists do not use turbulence products for decision-making purposes.*

Questionnaire Ratings

Question 5 – Strongly Agree, 4 – Agree, 3 – Borderline, 2 – Disagree, 1 – Strongly Disagree	GA pilots	Part 121 pilots	CWSU / AOC meteorologists	AOC dispatchers	1 HEMS pilot	WFO/NOAA meteorologists*
	Median (Mean) n					
Q6. The ability to alternate from deterministic turbulence information to probabilistic turbulence information would improve situational awareness of turbulence locations and severity.	3.5 (3.58) n=12	4 (4.0) n=3	5 (4.5) n=6	5 (4.0) n=3	5	4.5 (4.25) n=4

GA pilots had a Borderline response of 3.5 stating the ability to alternate from deterministic turbulence information to probabilistic turbulence information may or may not provide more situational awareness of turbulence locations and severity. This is due to GA pilots having difficulty interpreting the probabilistic turbulence forecast. Alternating between the forecasts increased workload and provided too much information to comprehend.

**Note: WFO/NOAA meteorologists do not use turbulence products for decision-making purposes.*

Questionnaire Ratings

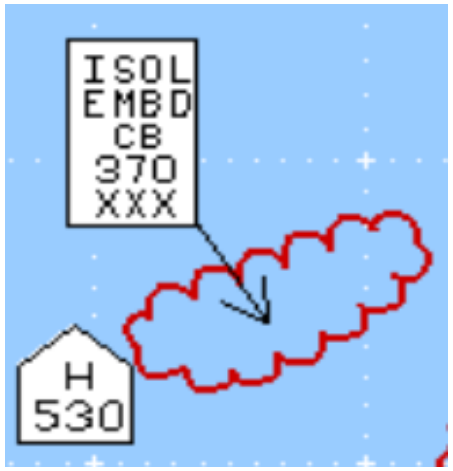
Question 5 – Strongly Agree, 4 – Agree, 3 – Borderline, 2 – Disagree, 1 – Strongly Disagree	GA pilots	Part 121 pilots	CWSU / AOC meteorologists	AOC dispatchers	1 HEMS pilot	WFO/NOAA meteorologists*
	Median (Mean) n					
Q7. I would use a probabilistic turbulence product for operational decision-making.	4 (4.0) n=12	4 (4.0) n=3	4 (3.83) n=6	4 (4.3) n=3	5	5 (4.0) n=3

**Note: WFO/NOAA meteorologists do not use turbulence products for decision-making purposes.*

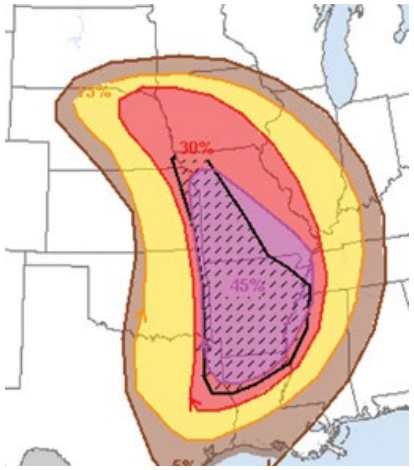
Display Format Preference

- Participants were asked rank preferences for several probabilistic graphical displays.
- Rankings were done using values 1-5. 1 represented the most preferred and 5 representing the least preferred.
- The 5 probabilistic graphical displays are displayed below.

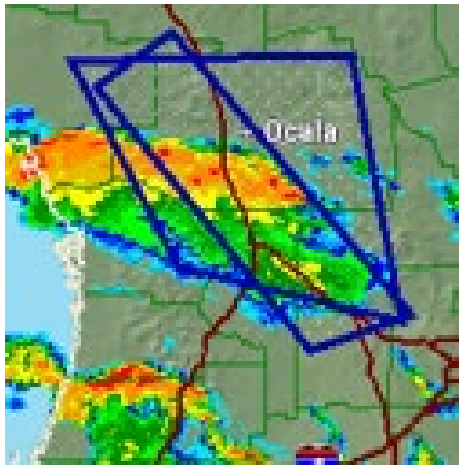
Bubble and Text



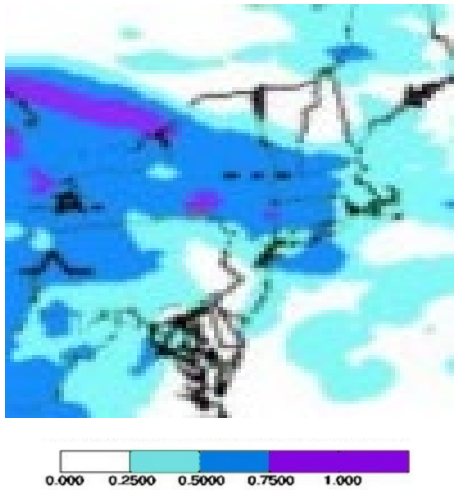
Shaded Percentages



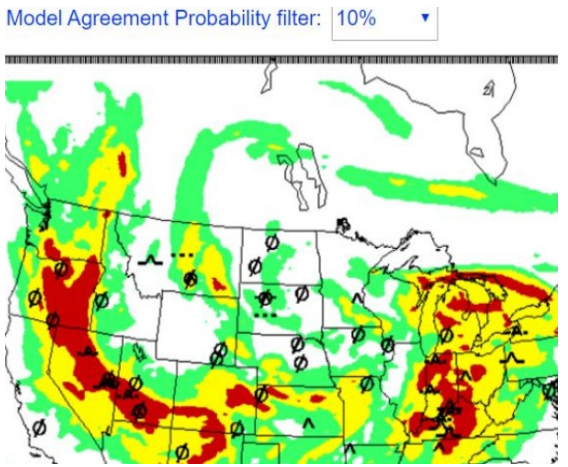
Polygons



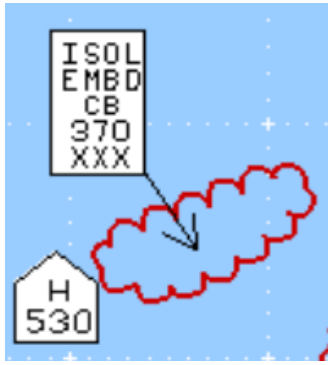
Shading with a legend

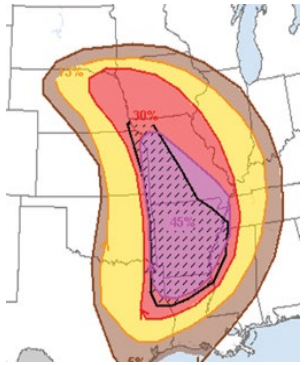


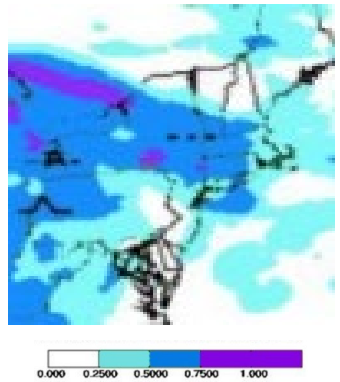
Selectable by Probability

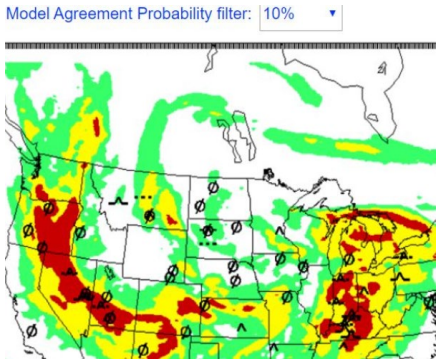


Display Format Preference



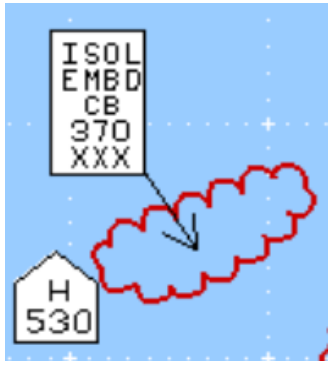


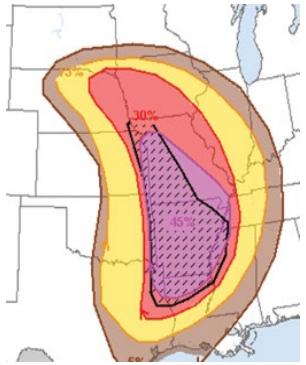


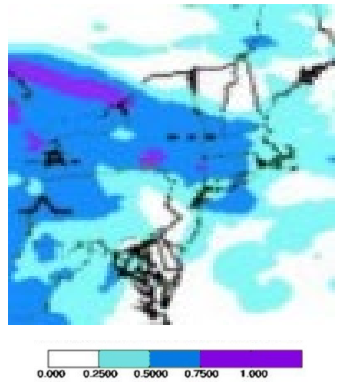


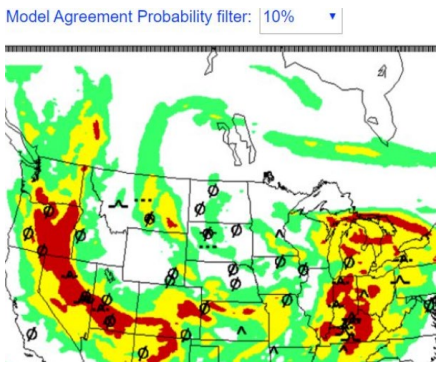
Ranking Results					
	Bubble and Text	Shaded Percentages	Polygons	Shading with a Legend	Selectable by Probability
GA pilots	5th (n=10)	1st-2nd (n=4/4)	4th (n=6)	3rd (n=8)	1st-2nd (4/4)
Part 121 pilots	2nd (n=2)	3rd (n=2)	4th (n=2)	5th (n=2)	1st (n=1)
CWSU meteorologists	5th (n=2)	2nd (n=2)	4th (n=2)	3rd (n=2)	1st (n=2)
WFO meteorologists	4th (n=1)	1st and 2nd (n=1/1)	5th (n=2)	1st and 4th (n=1/1)	2nd (n=1)
NOAA meteorologists	5th (n=2)	2nd and 3rd (n=1)	4th (n=2)	1st and 2nd (n=1/1)	1st and 3rd (n=1)
AOC meteorologists	4th and 5th (n=1/1)	1st and 3rd (n=1/1)	4th and 5th (n=1)	2nd and 3rd (n=1)	2nd (n=1)
		2nd Highest Ranking		3rd Highest Ranking	Highest Ranking

Display Format Preference









Ranking Results					
	Bubble and Text	Shaded Percentages	Polygons	Shading with a legend	Selectable by Probability
AOC dispatchers	4th and 5th (n=1/2)	3rd (n=2)	2nd and 4th (n=1/1)	2nd and 4th (n=1/1)	1st and 2nd (n=2/1)
HEMS pilot	5th	1st	4th	2nd	3rd
		2nd Highest Ranking		3rd Highest Ranking	1st Highest Ranking

Objective 1 Summary

Determine how users could utilize and interpret a probabilistic turbulence forecast.

- VFR GA pilots had difficulty interpreting and understanding the probabilities in the turbulence forecast. GA pilots rely on perception and C&V to infer where turbulence may occur.
- IFR GA pilots could interpret the probabilistic turbulence forecast and use it to determine altitudes and routes particularly when flying with passengers.
- Part 121 pilots would use the probabilistic turbulence forecast with the deterministic forecast. The probabilities would be used to determine the likelihood and severity of the turbulence occurring. The forecasts would be used to determine safe altitudes and routes.

Objective 1 Summary Continued

- CWSU and AOC meteorologists and AOC dispatchers would us the probabilistic turbulence forecast in conjunction the deterministic forecast to aid in determining routes and altitudes that are less likely to encounter turbulence.
- WFO and NOAA meteorologists would use the probabilistic turbulence forecast to identify areas that are likely to affected by the different severities of turbulence.
  - WFO meteorologists would use the forecast to provide more granularity to aviation briefings.
  - NOAA meteorologists would the use the forecasts to verify and validate forecasts in other products.

Objective 2 Summary

Determine what information is needed in a probabilistic turbulence forecast to support operational decision-making.

- GA pilots, WFO meteorologists and NOAA meteorologist do not use turbulence forecasting products for decision-making purposes.
- Part 121 pilots stated the need for the following:
  - Capability to view both probabilities and severity at one time. But, having the capability to view them separately either on different displays or toggle on/off the forecasts.
  - Capability to enter and display routes and zoom into the routes to view turbulence along the route.
  - Capability to select aircraft type.
  - Capability to select different altitudes.
  - Capability to toggle on/off PIREPs, AIRMETs, and SIGMETs.
  - Capability to toggle on/off the jet stream.

Objective 2 Summary

Determine what information is needed in a probabilistic turbulence forecast to support operational decision-making.

- CWSU and AOC meteorologists and AOC dispatchers stated the need for the following:
  - Clear and distinct probability definitions.
  - Capability to view both probabilities and severity using one display or on different displays side-by-side.
  - Capability to enter and display routes and zoom into the routes to view turbulence along the route.
  - Capability to select aircraft type.
  - Capability to select different altitudes.
  - Capability to toggle on/off PIREPs, AIRMETs, and SIGMETs.
  - Capability to toggle on/off the jet stream.

Backup Slides

Participants

Group/Location	FAA WJHTC (Summer Experiment/Webex)	Kansas City (Summer Experiment)	Airline AOCs (On site)	Total
GA pilots	9	3	-	12
121 pilots	-	-	3	3
CWSU meteorologists	-	4	-	4
WFO meteorologists	-	2	-	2
NOAA meteorologists	-	2	-	2
AOC meteorologists	1	1	2	4
AOC dispatchers	7		5	12
HEMS pilot	-	1	-	1
Total	17	13	10	40

Interview Question Responses

Question 1: Before today, were you familiar with the term Eddy Dissipation Rates (EDR)?	
Group	Summary of responses
GA pilots (n =12)	A majority of the GA pilots (9 of 12) were NOT familiar with the term EDR
Part 121 pilots (n=3)	All 121 pilots were familiar with the term EDR
CWSU meteorologists(n=4)	All CWSUs were familiar with the term EDR
WFO meteorologists (n=2)	Both WFO meteorologists were not familiar with the term EDR
NOAA meteorologists (n=2)	One of the two NOAA meteorologists was familiar with the term EDR
AOC meteorologists (n=4)	All of the AOC meteorologists were familiar with the term EDR
AOC dispatchers (n=12)	A majority were familiar with EDR (8). One of the dispatchers was not sure and three other dispatchers did not know the term EDR.
HEMS Pilot (n=1)	The HEMS pilot was not familiar with EDR.

Interview Question Responses

Question 2: Have you used the GTG Turbulence Product? If so, how often?	
Group	Summary of responses
GA pilots (n =12)	A majority of the GA pilots do not use GTG. Many pilots that are VFR don't use turbulence products. The three that had use it, use it infrequently and not as a primary source of information.
Part 121 pilots (n=3)	All 121 pilots use it as an advisory product along with other turbulence products.
CWSU meteorologists(n=4)	All four CWSU meteorologists use GTG regularly; one used it once or twice a month since they are a manager.
WFO meteorologists (n=2)	All WFO meteorologists did not use GTG .

Interview Question Responses

Question 2: Have you used the GTG Turbulence Product? If so, how often?	
Group	Summary of responses
NOAA meteorologists (n=2)	One of the two NOAA meteorologists used GTG .
AOC meteorologists (n=4)	Three of the four AOC meteorologists use GTG, but not often since they use other turbulence products. The fourth meteorologist uses another turbulence product from their airline.
AOC dispatchers (n=12)	Ten of the 12 AOC dispatchers use the GTG product, approximately half of them regularly.
HEMS Pilot (n=1)	The HEMS pilot did not use the GTG product as it was stated they do not need to know about turbulence often.

Interview Question Responses

Question 4: How would you interpret a 20% chance of moderate turbulence over a region?	
Group	Summary of responses
GA pilots (n =12)	The majority responded that 20% of there will be moderate turbulence over the entire area and 80% chance there would not be.
Part 121 pilots (n=3)	Mixed responses, with one responding that 20% of chance of turbulence happening in the area and another responding with 20% of the sky having turbulence pockets. The third pilot stated it would need to be defined well with an ability to zoom in on the map.
CWSU meteorologists(n=4)	Mixed responses, with a mix of 20% chance of turbulence over the entire area or 20% over a spot with the other two CWSUs not confident to interpret the question.

Interview Question Responses

Question 4: How would you interpret a 20% chance of moderate turbulence over a region?	
Group	Summary of responses
WFO meteorologists (n=2)	One responded a 20% chance happening within the whole area and the other a 20% chance of it occurring somewhere in that area.
NOAA meteorologists (n=2)	Both NOAA meteorologists responded that 20% chance of something happening in the area.
AOC meteorologists (n=4)	Mixed responses wither either a 20% chance of turbulence happening at a point within the area or 20% of the area will experience turbulence and 80% will not.
AOC dispatchers (n=12)	Most responded a 20% chance of turbulence happening at any point in the area. Others responded the whole region would experience turbulence 20% of the time.
HEMS Pilot (n=1)	No comment

Interview Question Responses

Question 5: Would you use a probabilistic turbulence forecast?	
Group	Summary of responses
GA pilots (n =12)	Most would use it to confirm what other weather tools are giving them as it gives more information. A few participants said they don't use turbulence products. A couple participants noted that they would use the deterministic and not the probabilistic.
Part 121 pilots (n=3)	All would for more information about the percentage probability to make decisions about going around or through turbulence.
CWSU meteorologists(n=4)	Mixed responses, with some saying they would use to self-brief to determine what to tell others and others saying it depended on the performance.

Interview Question Responses

Question 5: Would you use a probabilistic turbulence forecast?	
Group	Summary of responses
WFO meteorologists (n=2)	Both would use it as a briefing tool and to see if other tools are needed. Would find it useful if they had a threshold in mind to make a decision.
NOAA meteorologists (n=2)	Yes, both would look at various options and the model agreement.
AOC meteorologists (n=4)	All said they would use it if one was available. A couple participants said that they would use it in conjunction with PIREPs and other weather products to determine trends.
AOC dispatchers (n=12)	All said they would use it for more information to see trends on turbulence dissipating or moving to determine to go around or through it.
HEMS Pilot (n=1)	No comment

Interview Question Responses

Question 6: Is it easy to interpret a turbulence forecast? Why or why not?	
Group	Summary of responses
GA pilots (n =12)	A majority said it is easy to interpret. Some said it is easier to interpret with a dual type display with both deterministic and probabilistic category information shown.
Part 121 pilots (n=3)	All said that as long as it is defined properly and after using it a while, users would be able to understand probability, not agreement of models.
CWSU meteorologists(n=4)	All said that as long as probability is explained properly with the color contrasts.
WFO meteorologists (n=2)	Mixed responses of yes it is easy to use but some will have issues based on their understanding of what the percentage means.
NOAA meteorologists (n=2)	Both said it is easy to interpret as long as the probability is defined.
AOC meteorologists (n=4)	Most said it was easy to interpret with one saying it is not easy to use because it does not tell you what is causing turbulence or how wide spread it is.
AOC dispatchers (n=12)	All said that as long as it is defined properly and after using it a while, users would be able to understand probability, not agreement of models.
HEMS Pilot (n=1)	No comment

Interview Question Responses

Question 7: Would you use a deterministic and a probabilistic turbulence forecast simultaneously for decision making?	
Group	Summary of responses
GA pilots (n =12)	Mixed responses. Some would use the one they were familiar with, others would use only deterministic, others would use only probabilistic, some said they would use both to confirm with each of the displays.
Part 121 pilots (n=3)	Most said they would use it in conjunction with each other side by side. One said participant said that it would be easier to use if they had fewer charts to look at a quick glance. Too much info would be too hard to read quickly.
CWSU meteorologists(n=4)	All responded they would use both to be able to compare to make their decisions.

Interview Question Responses

Question 7: Would you use a deterministic and a probabilistic turbulence forecast simultaneously for decision making?	
Group	Summary of responses
WFO meteorologists (n=2)	All said they would use both. One said they would look at the deterministic, but make their decision based on the probabilistic.
NOAA meteorologists (n=2)	All said that they would use both in one display.
AOC meteorologists (n=4)	All said they would use both. One said it would depend on the length of flight. A short flight would be deterministic and probabilistic for longer flights.
AOC dispatchers (n=12)	All would use both at the same time. Half would use the GTG deterministic forecast and use the probabilistic as a secondary tool.
HEMS Pilot (n=1)	Would like to keep the displays next to each other to compare.

Interview Question Responses

Question 8: What probability/threshold for EDR/light, moderate and severe turbulence would cause you to modify a route?	
Group	Summary of responses
GA pilots (n =12)	All said they would fly through light turbulence no matter they probability. For moderate and severe turbulence, the threshold would be much less, between 30 to 50% for severe and moderate respectively. One stated the greater or equal to for each category is confusing.
Part 121 pilots (n=3)	All said they would fly through light turbulence no matter the probability. For moderate turbulence, mixed responses were given. Some said it would depend on the stage of the flight to plan on what to do and another said they would go around as needed. For severe turbulence. For severe, any percentage they would not fly through it.
CWSU meteorologists(n=4)	Most said for light turbulence, it would have no effect on their decision. One said 60-70% probability for light turbulence would make them modify a route. For moderate turbulence, a 40-80% probability change would cause the participants to modify their route. For severe turbulence, percentage would be lower than moderate for them to modify a route.

Interview Question Responses

Question 8: What probability/threshold for EDR/light, moderate and severe turbulence would cause you to modify a route?	
Group	Summary of responses
WFO meteorologists (n=2)	Mixed responses. One said for light turbulence, the probability wouldn't matter as they would fly through at any probability. The other said at 80% they would modify the route. For moderate and severe, one said they would wait for PIREPs and the other said at 20% probability of severe turbulence, they would think more about their decision.
NOAA meteorologists (n=2)	Mixed responses with one saying they would fly through light turbulence no matter what while the other participant responded the threshold being 50% probability or greater for modifying a route. They were not sure for the moderate or severe probability threshold.

Interview Question Responses

Question 8: What probability/threshold for EDR/light, moderate and severe turbulence would cause you to modify a route?	
Group	Summary of responses
AOC meteorologists (n=4)	All said that for light turbulence, they would not modify a route no matter what the probability was. For moderate turbulence, the threshold would be between 40-60%. For severe turbulence, some said that any percentage would need to discuss options while another said severe at 40% would cause them to discuss options for modifying a route.
AOC dispatchers (n=12)	Mixed responses. Some said they would fly around light turbulence no matter what, while others said they would not deviate for any light turbulence. For moderate, anything greater than 50%, they would consider modifying the route. For severe, any probability percentage would prompt a discussion for modifying a route. Half of the participants said it would also depend on the duration and exposure to intensity.
HEMS Pilot (n=1)	No comment

Interview Question Responses

Question 9: How would you prefer the probability data to be displayed? (33.3%, 0.33, or as 5 out of 15)	
Group	Summary of responses
GA pilots (n =12)	Most said that they would like to see it displayed as a percentage. One said to display it as a decimal.
Part 121 pilots (n=3)	All said they would prefer the data to be displayed as a percentage.
CWSU meteorologists(n=4)	All said they would prefer the data to be displayed as a percentage with one also saying to list the #/# of total diagnostics.
WFO meteorologists (n=2)	Participant said they would prefer the data listed as a percentage.
NOAA meteorologists (n=2)	All said they would prefer the data to be displayed as a percentage.
AOC meteorologists (n=4)	All said they would prefer the data to be displayed as a percentage.
AOC dispatchers (n=12)	Mixed responses, half said they would prefer the data to be displayed as a percentage and the other half wanted it to be selectable by probability filter, similar to the probability mock-up GUI.
HEMS Pilot (n=1)	No comment

Interview Question Responses

Question 10. When viewing a probabilistic turbulence forecast, is it valuable to see the separate probability for each EDR/severity level?	
Group	Summary of responses
GA pilots (n =12)	Most said yes it is valuable to see each the probability for each turbulence severity level.
Part 121 pilots (n=3)	All said yes it is valuable to see the separate probability for each turbulence severity level. Would also like ability to pick a spot to get exact probability.
CWSU meteorologists(n=4)	Most said yes it would be valuable to see the separate probability for each turbulence level. One stated they would like gradients of color that correspond to the probability.
WFO meteorologists (n=2)	Both said they it would be valuable to see the separate probability for each turbulence level as it would provide the full picture for decision making.

Interview Question Responses

Question 10. When viewing a probabilistic turbulence forecast, is it valuable to see the separate probability for each EDR/severity level?	
Group	Summary of responses
NOAA meteorologists (n=2)	Both said they it would be valuable to see the separate probability for each turbulence level to be able to compare to make a decision.
AOC meteorologists (n=4)	Most said to see the probability separately, but to bin it by low, medium and high and have the ability to select a spot to get the actual percentage since each aircraft is affected differently by EDR.
AOC dispatchers (n=12)	Half said they would like to see the probability separately, but to bin it by low, medium and high and have the ability to select a spot to get the actual percentage. Severe and moderate would need different reactions. Some would like to be able to filter out certain probabilities at lower levels to make the display easier to read.
HEMS Pilot (n=1)	No comment

Interview Question Responses

Question 11. Would you want the ability to turn on/off different data sets used to develop the probabilistic turbulence forecast?	
Group	Summary of responses
GA pilots (n =12)	Most stated they would not want to be able to turn on/off the different data sets. It is too much information and not meant for pilots. A few stated they would like to be able to select models that are in most agreement or least agreement.
Part 121 pilots (n=3)	All stated they would not want the ability to toggle the data sets on/off. The meteorologist would like that ability.
CWSU meteorologists(n=4)	Half stated they would like to be able to, with the other half saying no since could mess with the probabilities and make things more complicated.
WFO meteorologists (n=2)	Both stated they would like this ability to see which data sets aren't working and to give increased confidence of agreements.
NOAA meteorologists (n=2)	Both stated they would like this ability.
AOC meteorologists (n=4)	Most of the participants stated they would like the ability to turn on/off data sets, with one saying they would not want it.
AOC dispatchers (n=12)	All stated they would trust what the meteorologists choose for them.
HEMS Pilot (n=1)	No comment

Interview Question Responses

Question 12. When using a probabilistic turbulence forecast, what is the optimal color coding scheme or preference?	
Group	Summary of responses
GA pilots (n =12)	Almost all that responded said that they would like colors for probability different from the severity colors. Some would like to see a stippling or hatch pattern. One responded they would use the same GTG colors but with a different scale.
Part 121 pilots (n=3)	Mixed responses. Responses were using several shades of the same color to blend light, moderate and severe turbulence. One wanted shades of orange and one wanted to use hath patterns overlapping the severity levels of red/yellow/green.
CWSU meteorologists(n=4)	All responded stated the colors should be different than the ones used for severity.
WFO meteorologists (n=2)	Mixed responses. One preferred the same colors as GTG severity and the other preferred to use a different color scheme since red/yellow/green already has a certain meaning.

Interview Question Responses

Question 12. When using a probabilistic turbulence forecast, what is the optimal color coding scheme or preference?	
Group	Summary of responses
NOAA meteorologists (n=2)	Both responded they would like the probability colors to be different from severity.
AOC meteorologists (n=4)	Mixed responses. One wanted the same color scheme as GTG severity, while others wanted several shades of the same colors for light moderate and severe and another suggested examining other colors.
AOC dispatchers (n=12)	Mixed responses. Some wanted probability colors for only light, moderate and severe (not greater or equal to each level) based on percentages, others wanted different shades of orange and others wanted hatch marks to represent probability over severity colors. Some also would like the GTG severity colors with the probability filter dropdown similar to the mock-up GUI.
HEMS Pilot (n=1)	Specific colors per severity level, so you know what you are seeing without reading it.

Interview Question Responses

Question 13. What is your preferred wording when describing the probabilistic turbulence forecast? (light moderate, severe; EDR value; isolated, frequent; percentage number)	
Group	Summary of responses
GA pilots (n =12)	Most responded that they preferred light, moderate and severe and that it should have information to explain further.
Part 121 pilots (n=3)	Most preferred low medium and high or light moderate and severe. One noted it they need to know what the words mean while they are training on the tool
CWSU meteorologists(n=4)	Mixed responses. One preferred light, moderate and severe, one NIL, light chop, clear air, light mountain wave turbulence, and extreme, one preferred percentages.

Interview Question Responses

Question 13. What is your preferred wording when describing the probabilistic turbulence forecast? (light moderate, severe; EDR value; isolated, frequent; percentage number)	
Group	Summary of responses
WFO meteorologists (n=2)	Mixed responses. One preferred light, moderate, and severe and another preferred EDR based.
NOAA meteorologists (n=2)	Mixed responses. One preferred light, moderate, and severe, and one preferred EDR for the different aircraft types.
AOC meteorologists (n=4)	All preferred low, medium and high or light moderate, and severe with percentage numbers so it is easy to train.
AOC dispatchers (n=12)	Most preferred to use light, moderate, and severe with one preferring percentage as long as it is defined.
HEMS Pilot (n=1)	Percent number

Interview Question Responses

Question 14. How would you want a probabilistic turbulence forecast displayed? (i.e. overlaying high, medium, low, EDR value?)	
Group	Summary of responses
GA pilots (n =12)	Mixed responses • Shaded by light, moderate, and severe by percentage. • Would not want it overlapped. • Some would like a side by side of severity and probability similar to mock-up GUI. • Just want to know if there is turbulence or not. • No preference. • Groups of light, moderate and severe for probability button names, but would still use greater or equal than for light, moderate, and severe.
Part 121 pilots (n=3)	Mixed responses • Have a threshold or percent you could filter out, similar to the probability filter mock-up GUI. • Ability to overlay but toggle off the overlay. • Vertical profile for flight planning.

Interview Question Responses

Question 14. How would you want a probabilistic turbulence forecast displayed? (i.e. overlaying high, medium, low, EDR value?)	
Group	Summary of responses
CWSU meteorologists(n=4)	Mixed responses • Overlay in layers of light, moderate, and severe. • EDR doesn't do well in mountain wave, so you would still need categories. • Needs to be customizable for the audience.
WFO meteorologists (n=2)	Mixed responses • Too much clutter if you overlay. • Prefer it side by side or toggle for probability.
NOAA meteorologists (n=2)	Both would like to have light, moderate, and severe shown on different screens.

Interview Question Responses

Question 14. How would you want a probabilistic turbulence forecast displayed? (i.e. overlaying high, medium, low, EDR value?)	
Group	Summary of responses
AOC meteorologists (n=4)	Mixed responses • Some preferred to have them by light, moderate, and severe. • One would like a 3D view plotted by time on a flight path. Customized profile of risk on a route.
AOC dispatchers (n=12)	Mixed responses • Would have separate bins for light, moderate, and severe and vary the color based on altering the shades of color. • Ability to overlay but toggle on/off the overlay. • Vertical profile for flight planning, because having to click different altitude levels is time consuming. • Drop down probability similar to the probability filter mock-up GUI.
HEMS Pilot (n=1)	Side by side with EDR values similar to the side by side mockup-GUI.

Interview Question Responses

Question 15. Which features would you want customizable for your site? i.e. severity thresholds, information displayed (EDR vs. percentage), color scheme used?	
Group	Summary of responses
GA pilots (n =12)	• Ability to set threshold for severe turbulence for no go decisions. • No change from dual mockup side by side GUI. • Clean option with no PIREPs/METAR overlays. • A route planner to draw a route integrated in it. • Ability to turn on/off layers of probability. • Ability to show CAT vs convection thunderstorms. • Altitudes, time scale and ability to zoom in. • Ability to show history/trends of turbulence. • Ability to see the jet stream and wind information.
Part 121 pilots (n=3)	• All pilots would like to be able to enter in a flight plan and be able to zoom over a route to see where turbulence is located. • Would like to filter for their airplane using some type of artificial intelligence so they can make a quick decision to go up, down, etc.

Interview Question Responses

Question 15. Which features would you want customizable for your site? i.e. severity thresholds, information displayed (EDR vs. percentage), color scheme used?	
Group	Summary of responses
CWSU meteorologists(n=4)	• Would like the ability to have adjust their levels of EDR and severity to “filter out the noise”. • Have the ability to download the data to reprocess it. • Would like to set thresholds and color schemes, • Make same color schemes for everyone so it is standardized.
WFO meteorologists (n=2)	• Ability to set thresholds for a percentage or greater to set and reduce other information. • Would like to be customizable such as thresholds for each severity level, with a default color scheme.
NOAA meteorologists (n=2)	• Percentage of agreement, allow user to filter out other data. • Default to something easy and then have option to pick customizations

Interview Question Responses

Question 15. Which features would you want customizable for your site? i.e. severity thresholds, information displayed (EDR vs. percentage), color scheme used?	
Group	Summary of responses
AOC meteorologists (n=4)	• Be able to customize to type of aircraft, domains going over to Hawaii since it is a new route. • Zoom over a route. • Group by low, medium, high, percentages. • Ability to overlay filtered reports by altitude for relevance. • Ability to define an area by drawing a polygon to see the severity they are interested in.
AOC dispatchers (n=12)	• Zoom over a route. • Group by low, medium, high percentages. • Ability to overlay filtered reports by altitude for relevance. • Ability to enter in a flight plan and be able to zoom over a route to see where turbulence is located. • Profile view. • Different risk thresholds.
HEMS Pilot (n=1)	• Option to show additional info on where the probabilities are coming from. • Customize for lower atmosphere.

Interview Question Responses

Question 16. Are there other critical pieces of information that are needed in a probabilistic turbulence forecast to inform decision making?	
Group	Summary of responses
GA pilots (n =12)	• PIREP overlay. • Jet stream, front overlays to toggle on/off. • Real time probability gauge. • Ability to click on a point and get exact probability. • Change the Max altitude level to an altitude that you want instead of all altitudes. • Ability to toggle on/off Prog Chart data. • Ability to know if it is clear air turbulence or a storm.
Part 121 pilots (n=3)	• Ability to zoom in over routes. • PIREPs and SIGMETs overlaid. Ability to filter altitude for PIREPs. • Predicting convective turbulence within 5-10 minutes. • Want it differentiated by severity and wouldn't want 40% moderate to mask out 100% light turbulence.

Interview Question Responses

Question 16. Are there other critical pieces of information that are needed in a probabilistic turbulence forecast to inform decision making?	
Group	Summary of responses
CWSU meteorologists(n=4)	• Real time EDR data to overlay on top of probability map. • Add moderate chop to moderate turbulence on deterministic view. • On deterministic view, have a symbol that shows the lowest part of the turbulence layer to the highest. • Include San Juan's airspace. • Have ability to show the forecast with a mouse click from deterministic. • Full altitude layer needed.
WFO meteorologists (n=2)	• Would want to know if mountain wave is included.
NOAA meteorologists (n=2)	• PIREPs.

Interview Question Responses

Question 16. Are there other critical pieces of information that are needed in a probabilistic turbulence forecast to inform decision making?	
AOC meteorologists (n=4)	• Hawaiian domain and Caribbean. • Zooming in over routes. • PIREPs and SIGMETs overlaid. • Predictive convective turbulence within 5-10 minutes.
AOC dispatchers (n=12)	• Zooming over routes. • PIREPs and SIGMETs overlaid and ability to filter for altitude. • Want it differentiated by severity and wouldn't want 40% moderate to mask out 100% light turbulence. • Exportable text so that it could be read by an automated system. • Historical and future trends.
HEMS Pilot (n=1)	No comment.

Interview Question Responses

Question 17. How often do you expect elevated EDRs and do you consider elevated EDRs to be a rare or frequent event?	
Group	Summary of responses
GA pilots (n =12)	Mixed responses • Varied from 5% to 30% of flights. • Severe occur on a regular basis. • Rare not very often.
Part 121 pilots (n=3)	Most agree that elevated EDRs are infrequent and rare.
CWSU meteorologists(n=4)	Most said that it rare and a small percentage of the time and is seasonal, mostly around thunderstorms.
WFO meteorologists (n=2)	Both responded that elevated EDRs is relatively infrequent.
NOAA meteorologists (n=2)	A participant responded that light is frequent, moderate is rare.
AOC meteorologists (n=4)	Most responded that moderate turbulence is rare and usually in convective systems in spring and fall and winter.
AOC dispatchers (n=12)	• Infrequent in the summer and frequent in winter. • Severe is less than 1%.
HEMS Pilot (n=1)	Not often.