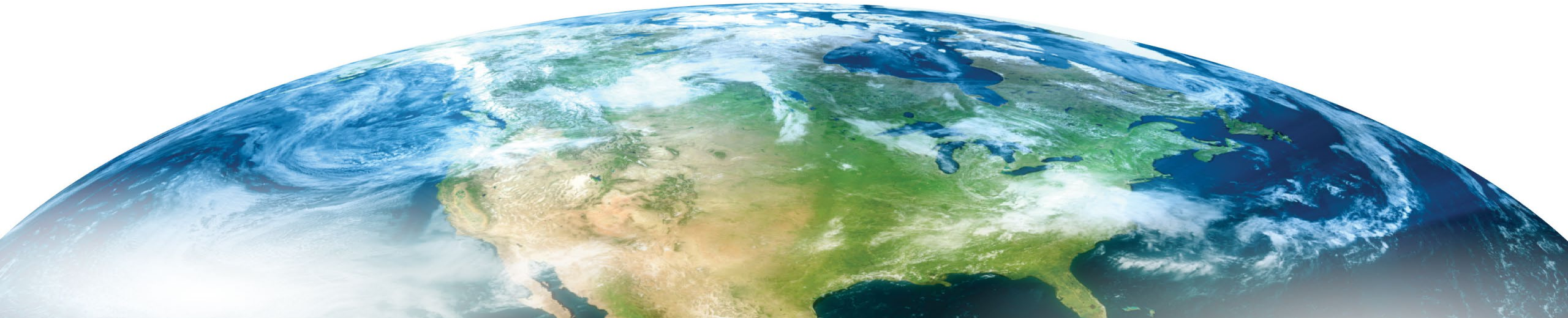
AWT/AWDE Probabilistic TCF Demo

Presented to: AWC
By: FAA AWDE Services, ANG-C63
Date: September 2020



Topics

- Introduction
- Background and Objectives
- Virtual Interview Approach
- Results
- Conclusions
- Recommendations

Introduction

Introduction

- National Oceanic and Atmospheric Administration's (NOAA) Aviation Weather Testbed (AWT) hosted the 2020 Virtual Summer Experiment August 3-14, 2020.
- AWT developed a Probabilistic Traffic Flow Management Convective Forecast (TCF) product, which displays the probability of convection exceeding sparse or medium coverage thresholds.
- The Federal Aviation Administration's (FAA) Aviation Weather Demonstration and Evaluation (AWDE) Services team, supported by AWT, conducted virtual interviews to determine the usefulness and optimal presentation of a probabilistic summary of convective threats based on TCF criteria.

AWC Aviation Weather Testbed Summer Experiment 2020. https://testbed.aviationweather.gov/content/page?name=summer_exp_2020

Background and Objectives

Background

- The TCF and extended TCF (eTCF) products currently provide individual snapshots of expected convective coverage and echo top heights.
  - The TCF produces a forecast every two hours for a 4-8 hour forecasts.
  - The eTCF produces a forecast every two hours for a 10-30 hour forecasts.
- The AWT developed a product to provide the probability of convection exceeding TCF sparse or medium coverage thresholds and associated echo top heights.
- The Probabilistic TCF graphic displays a summary of convective threats over the next 24 hours to supplement the final TCF and eTCF products.
- Probabilistic forecast guidance was generated from the operational High Resolution Ensemble Forecast (HREF) and the experimental High Resolution Rapid Refresh (HRRRe) models.

AWC Aviation Weather Testbed Summer Experiment 2020. https://testbed.aviationweather.gov/content/page?name=summer_exp_2020

Objectives

- Determine the suitability of a probabilistic summary of convective threats for a 24 hour time period based on TCF criteria.
- Determine how to design the Probabilistic TCF product including:
  - Determining information needed for decision making.
  - Determining how to present probabilistic information for decision making.
- Determine user preference for model guidance performance.

Virtual Interview Approach

Participant Summary

Total	User Group
15	Center Weather Service Unit (CWSU) meteorologists
2	National Airspace Meteorologists (NAMs)
2	FAA PERTI Team Member
1	FAA/former CWSU meteorologist
1	Weather Research and Development Engineer
21	**Total**

Approach

- Participants registered for AWT accounts to access the Probabilistic TCF product.
- Once registered, participants used the Probabilistic TCF product as a supplemental tool during operations and/or interacted with the product during non-operational hours.
- AWT conducted an introduction session at the beginning of each week to demonstrate the Probabilistic TCF product and answer participant questions regarding the use of the product.
- Virtual interviews were conducted with one participant at a time via Google Meets.
- AWT team members attended each virtual interview session to provide subject matter expertise (SME) concerning product development.
- Each interview consisted of:
  - Introduction of AWT and AWDE team members.
  - AWT provided an overview of the objectives and procedures of the virtual interview session.
  - AWDE team asked a set of structured interview questions focusing on determining the usefulness and information requirements needed in a Probabilistic TCF forecast.

Approach

- Upon completion of the interview, participants were asked to complete an online questionnaire consisting of:
  - 5-point Likert scale rating (5-Strongly Agree, 4-Agree, 3-Neither Agree/Disagree, 2-Disagree, and 1-Strongly Disagree).
  - Two questions with multiple choice options.
  - Additional space was provided for comments.
- AWT held Group Discussions at the end of each week where participants, developers, and other stakeholders discussed the Probabilistic TCF product in a group setting.

Results

Questionnaire Results

Probabilistic TCF Questionnaire Results

Question	Mean (Median) N=15*
1. The Probabilistic TCF forecast is useful to aid in operational decision making.	3.3 (3)
2. The Probabilistic TCF forecast graphic is easy to interpret.	4.0 (4)
3. The Probabilistic TCF forecast provides useful information needed to effectively communicate convective impacts with partners.	3.3 (3)
4. Which additional AWC convective product(s) do you believe would be most beneficial when used alongside the probabilistic TCF graphic?	N/A
5. Probabilistic information specific to TCF criteria adds value over more general convective probability information as seen in ECFP (If not familiar with the ECFP, please leave blank.)	N= 12** 3.8 (4)

*15 out of 21 participants submitted online questionnaires.

** 12 out of 15 participants answered the question. 3 participants were not familiar with ECFP.

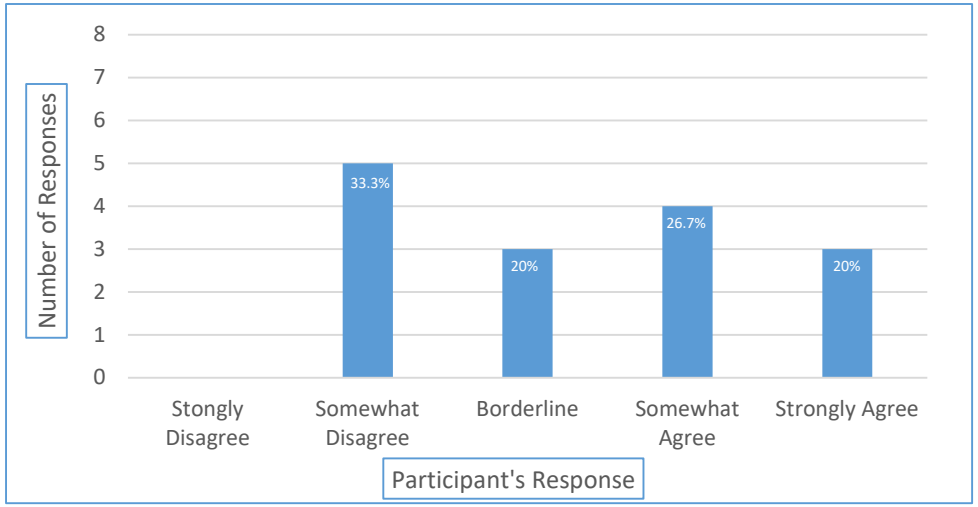
Probilistic TCF Questionnaire Results

Question	Mean (Median) N=15*
6. The ability to overlay the final TCF polygons provides additional information when using this graphic for decision making.	4.3 (4)
7. Focusing on the markings to indicate areas of TCF exceedance, do you prefer filled contours, outlines with hatching, or both.	N/A
8. The legend labeled "Exceedance Probabilities" is easy to understand.	3.8 (4)
9. The color coding used to represent the probabilities is easy to understand and distinguish from each other.	4.2 (5)
10. The ability to toggle the final TCF polygons between Sparse, Medium and ALL is beneficial.	4.4 (4)

*15 out of 21 participants submitted online questionnaires.

Probabilistic TCF Questionnaire Results

Question 1- The Probabilistic TCF forecast is useful to aid in operational decision making.

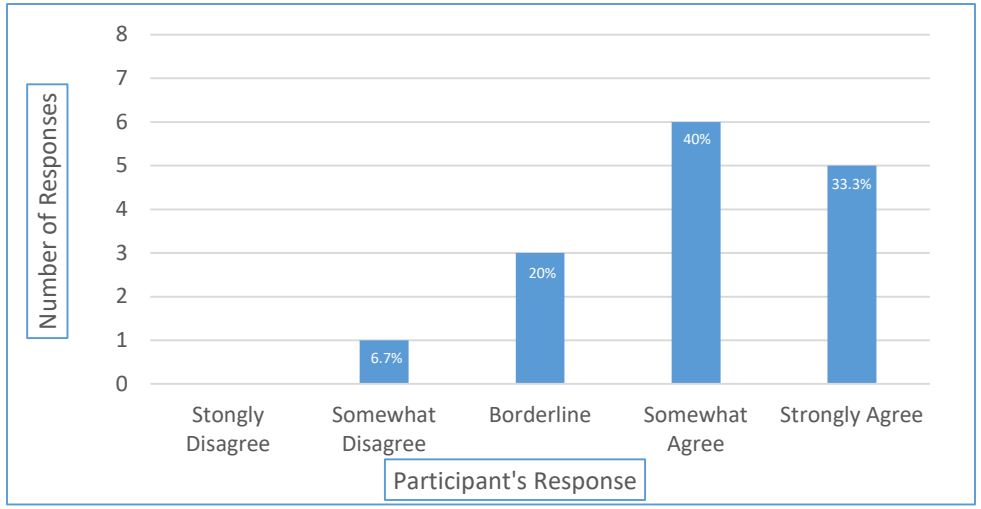


N= 15	
Mean	Median
3.3	3

- 3 participants “strongly agreed” and 4 “somewhat agreed” the Probabilistic TCF would be a useful aid in operational decision making. The participants stated the Probabilistic TCF provided a quick overview to determine areas of convection. 3 participants were “borderline” and 5 “somewhat disagreed” that the Probabilistic TCF would be a useful aid in decision making. The participants stated the 24 hour time window was not useful and smaller time frames (e.g. 2-3 or 4-6 hours) are needed for operational decision making.
- Participant Comments:
  - Provides a quick overview to determine the best areas of convection.
  - Provides a nice preview for potential “hot spots” of thunderstorm activity.
  - The time window is too long to make operational decisions/24 hour bin is not useful/need finer time bins/4-6 hour blocks.

Probabilistic TCF Questionnaire Results

Question 2- The Probabilistic TCF forecast graphic is easy to interpret.

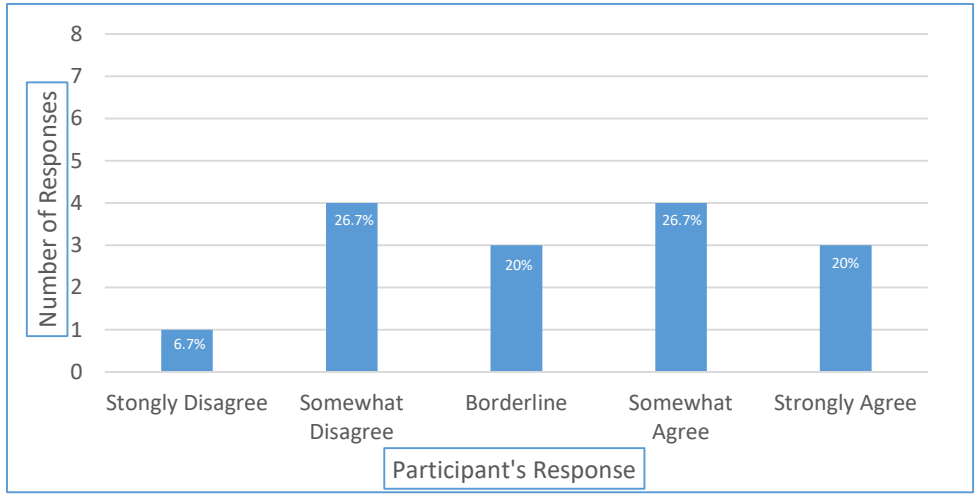


N= 15	
Mean	Median
4.0	4

- 5 participants “strongly agreed” and 6 “somewhat agreed” the Probabilistic TCF was easy to interpret. The participants stated the color coding for the probabilities was easy to distinguish and the graphic provided an adequate 24 hour overview of convection. 3 participants were “borderline” and 1 “somewhat disagreed” the Probabilistic TCF was easy to interpret. The participants stated the product should be accessible only to a meteorologist and not provided directly to the Traffic Management Unit (TMU) to ensure the information is interpreted correctly.
- Participant Comments:
  - The Multi-Radar Multi-Sensor (MRMS) and TCF polygons overlays got busy and need more color contrast.
  - Easy for CWSU forecasters to interpret, but not as easy for the traffic management unit.
  - Color coding for 25%, 50%, and 75% probabilities are very easy to distinguish.

Probabilistic TCF Questionnaire Results

Question 3. The Probabilistic TCF forecast provides useful information needed to effectively communicate convective impacts with partners.

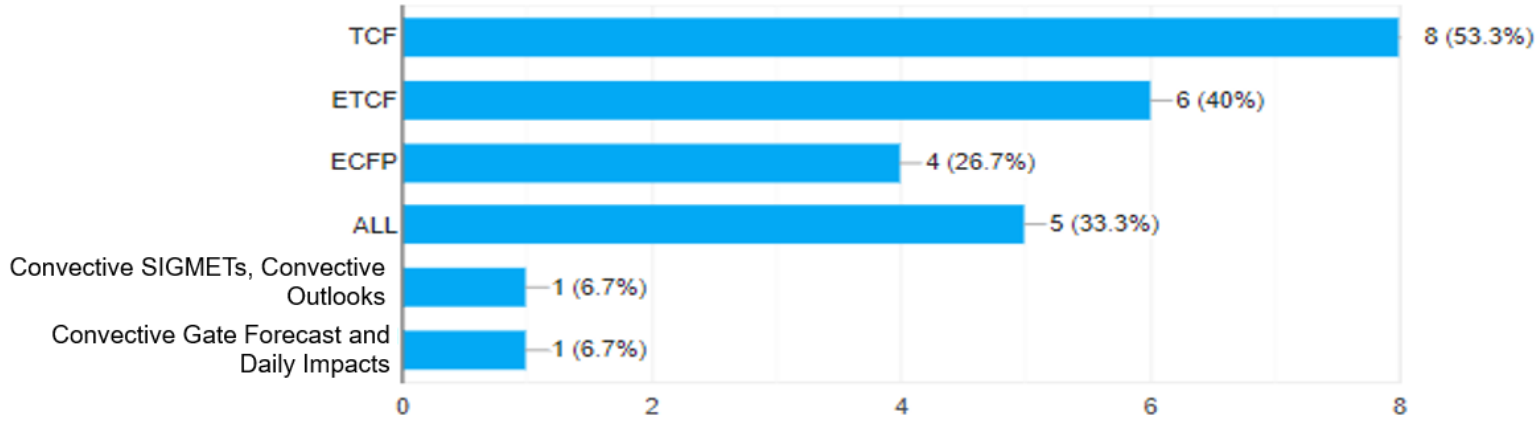


N= 15	
Mean	Median
3.3	3

- 3 participants “strongly agreed” and 4 “somewhat agreed” the Probabilistic TCF provided useful information to communicate convective impacts. The participants stated the product would provide a useful nationwide overview that could be used to identify areas where convection is likely to occur. 3 participants were “borderline”, 4 “somewhat disagreed”, and 1 “strongly disagreed” the Probabilistic TCF provided useful information to communicate convective impacts. Participants stated the tool should be used primarily by meteorologists, not by the TMU, to ensure information is interpreted correctly. Participants stated the 24 hour snapshot would provide a good national overview, however, for ARTCC’s the time frames need to be smaller such as 2-3 our 4-6 hour timeframes to effectively communicate convective impacts in a region.
- Participant Comments:
  - Too broadly brushed. The smaller time frames for the final TCF/eTCF are aligned to what a user wants to use.
  - Really lacking the time of the impact/ need 4 to 6 hour blocks.
  - Can easily determine where the best chance of convection will take place.
  - Great tool for meteorologists only. Non-meteorologists may misinterpret the information presented in the product.

Probabilistic TCF Questionnaire Results

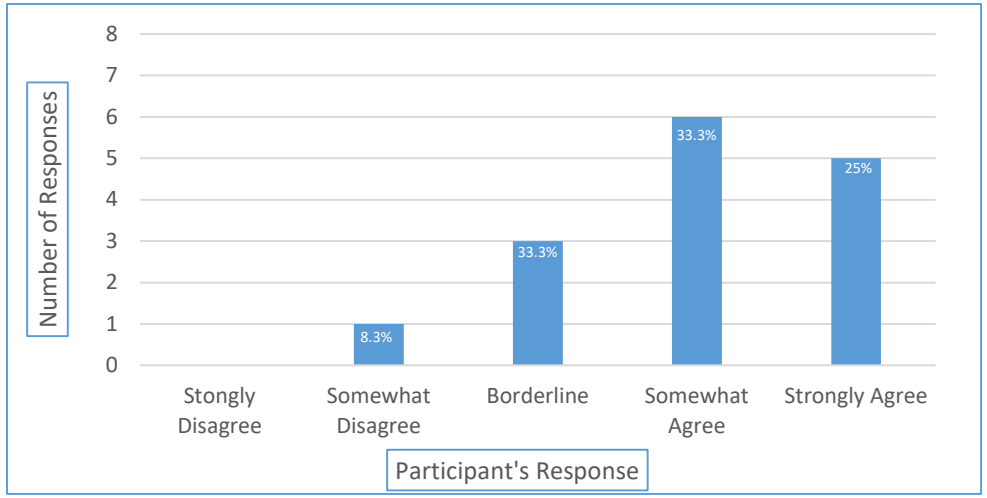
Question 4. Which additional AWC convective product(s) do you believe would be most beneficial when used alongside the Probabilistic TCF graphic?



- All participants stated the Probabilistic TCF would be used alongside other convective products as supplemental information to provide more confidence in the forecast. 8 participants would use the product with TCF, 6 participants would use the product with ETCF, 4 participants would use the product with ECFP, 5 participants would use the product with all other convective products, 1 participant would use the product with Convective SIGMETs, Convective Outlooks, and 1 participant would use the product with Convective Gate Forecast and Daily Impacts.
- Participant Comments:
  - If the Probabilistic TCF graphic remains a 24 hour forecast, will need the capability to toggle on the specific TCF and eTCF snapshots.
  - Would be beneficial to compare all of the above parameters to distinguish performance measures.

Probabilistic TCF Questionnaire Results

Question 5- Probabilistic information specific to TCF criteria adds value over more general convective probability information as seen in ECFP (If not familiar with the ECFP, leave blank.)

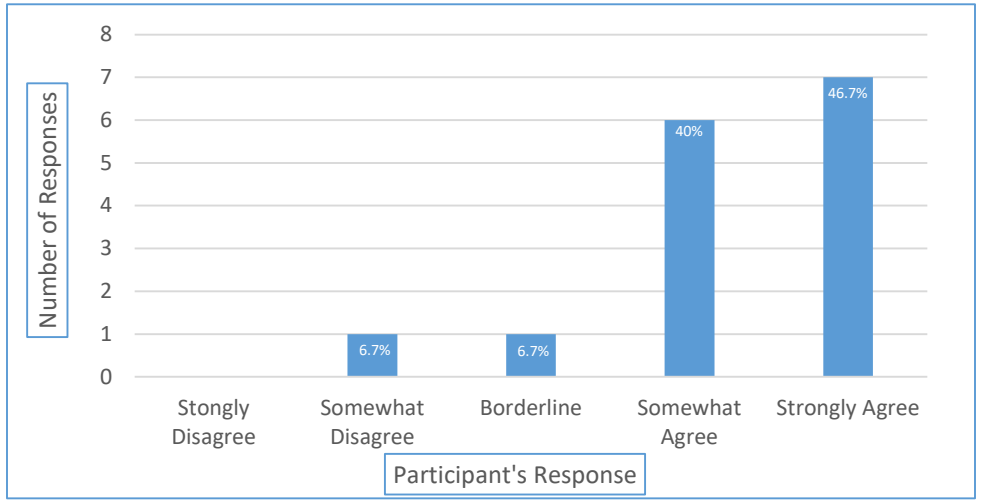


N= 12	
Mean	Median
3.8	4

- 5 participants “strongly agreed” and 6 “somewhat agreed” the TCF criteria added value over the general convective probability information because the TCF criteria is very specific and associated with a level of confidence. 3 participants were “borderline” and 1 “somewhat disagreed” the TCF criteria added value over the general convective probability information. Participants indicated both the TCF criteria and general convective information were useful and one didn’t add value over the other.
- Participant Comments:
  - The Probabilistic TCF adds value because the FAA is used to the TCF product.
  - Users may need finer resolutions, rather than a 24 hour smear, of the eTCF and ECFP, but if this can have finer temporal resolution then yes this could be more valuable.
  - ECPF has three thresholds for convection so unsure how much value can be added to this product outside of having two

Probabilistic TCF Questionnaire Results

Question 6. The ability to overlay the final TCF polygons provides additional information when using this graphic for decision making.

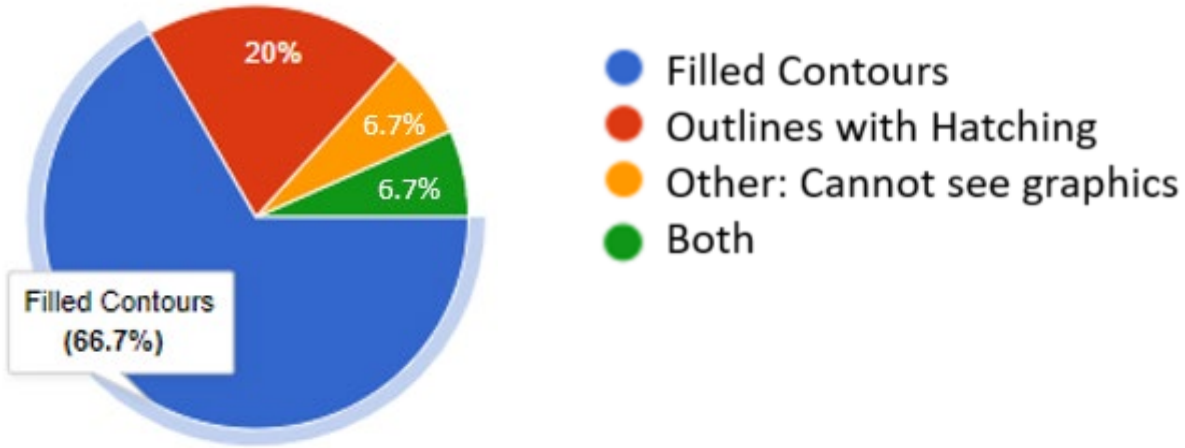


N= 15	
Mean	Median
4.3	4

- 7 participants “strongly agreed” and 6 “somewhat agreed” the ability to overlay the final TCF polygons provided additional information for decision making. Participants stated the TCF polygon overlays provided the capability to validate the Probabilistic TCF. 1 participant was “borderline” and 1 “somewhat disagreed” the ability to overlay the final TCF polygons provided additional information for decision making. The participants stated the additional information would not be useful to non-meteorologists.
- Participant Comments:
  - Beneficial to see which TCF polygons would be used for additional information.
  - Might be confusing to non-meteorologists.
  - Helps identify areas that meet criteria, but would not help FAA to show any overlay information.
  - Beneficial to help show where a sparse area could be considered a more marginal area or border lining a medium coverage area.

Probabilistic TCF Questionnaire Results

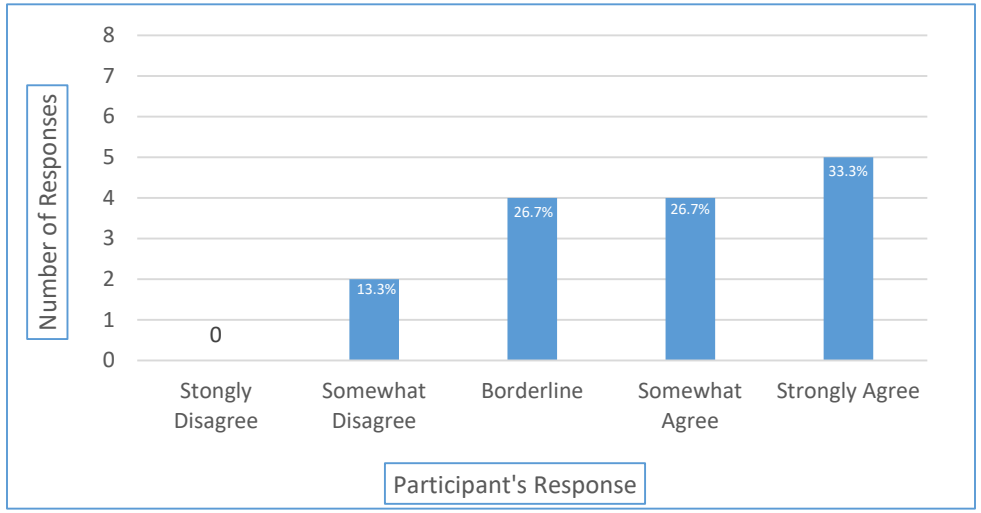
Question 7. Focusing on the markings to indicate areas of TCF exceedance, do you prefer filled contours, outlines with hatching, or both.



- 66.7% (10 out of 15) of participants would prefer to have filled contours to indicate areas of TCF exceedance. Participants stated the filled contours are easy to interpret and distinguish from one another. 20% (3 out of 15) of participants would prefer outlines and hatching to indicate areas of TCF exceedance because outlines and hatching is what the current TCF uses. 6.7% (1 out of 15) of participants preferred both equally and another selected other and stated “cannot see the graphics.”
- Participant Comments:
  - More visually appealing because it is easier to interpret how strong the threat is based on the assumptions of how the colors are chosen.
  - Filled contours are good for pre-analysis.
  - Filled contours are more easily distinguished than the hatching.

Probabilistic TCF Questionnaire Results

Question 8. The legend labeled “Exceedance Probabilities” is easy to understand.

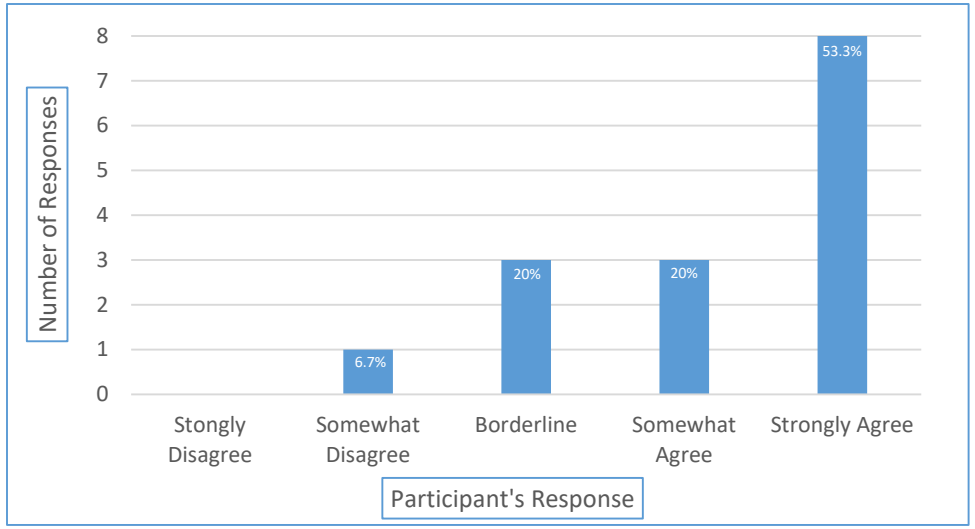


N= 15	
Mean	Median
3.8	4

- 5 participants “strongly agreed” and 4 “somewhat agreed” the term “Exceedance Probabilities” was easy to understand due to previous TCF experience. 4 participants were “borderline” and 2 “somewhat disagreed” the term “Exceedance Probabilities” was easy to understand. Participants stated the term may be easier for meteorologists and forecasters to understand, but may be misinterpreted by air traffic controllers without TCF experience.
- Participant Comments:
  - Would be easy to understand with CWSU/NAM guidance.
  - Unless you are a scientist, exceedance probabilities is not easy to understand.
  - Exceedance probabilities is easy to understand, but not something to show to FAA controllers.
  - The legend with the TCF valid times could be a little larger.

Probabilistic TCF Questionnaire Results

Question 9. The color coding used to represent the probabilities is easy to understand and distinguish from each other.

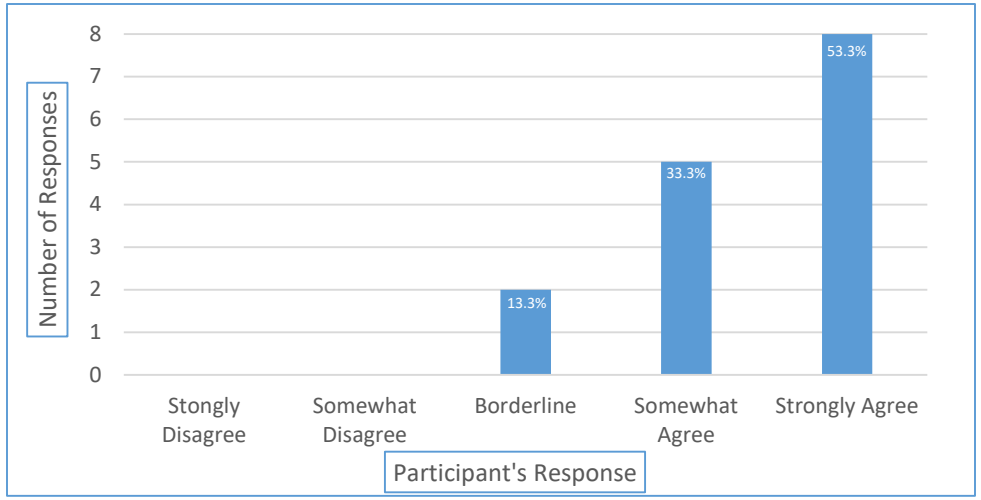


N= 15	
Mean	Median
4.2	5

- 8 participants “strongly agreed” and 3 “somewhat agreed” the color coding used to represent the probabilities was easy to understand and distinguish from each other. 3 participants were “borderline” and 1 “somewhat disagreed” the color coding used to represent the probabilities was easy to understand and distinguish from each other. Participants stated the colors used for the probabilities should have more contrast between each other to make each probability easier to distinguish.
- Participant Comments:
  - The probability legend can be seen clearly. However, individuals who are color blind may not be able to distinguish between the yellow and red colors.
  - The color coding is very easy to interpret.
  - Recommend a less intense colors, the TCF polygon colors are difficult to distinguish against the current colors used.

Probabilistic TCF Questionnaire Results

Question 10. The ability to toggle the final TCF polygons between Sparse, Medium and All is beneficial.



N= 15	
Mean	Median
4.4	5

- 8 participants “strongly agreed” and 5 “somewhat agreed” that the ability to toggle the final TCF Polygons between Sparse, Medium and all was beneficial to validate the Probabilistic TCF. 2 participants were “borderline” that the ability to toggle the final TCF Polygons between Sparse, Medium and all was beneficial. Participants stated the need to have the capability to view specific TCF polygon times and have the capability to turn on/off polygons to only view what is needed.
- Participant Comments:
  - Having two or three different sets of products on top of each other is hard to view.
  - Need a way to deselect polygons.
  - Further enhancement would be to have time toggles.
  - Need to filter by time.

Structured Interview Question Results

Question 1

Does the Probabilistic TCF graphic provide an adequate summary of the probability of impactful convection over the next 24 hours? Why or why not? What additional information would you need?

- Overall, participants agreed it was a good first look graphic that would provide an overview of the probability of convection in regions nationwide.
- The product provides a starting point to identify the likelihood of convection which will allow CWSUs to more effectively communicate the likelihood of traffic impacts to the TMUs.
- Provides a 24 overview for next day scheduling and international flights.
- This graphic would be used along side other models to compare convective focus areas for planning.

Question 1 (Continued)

- Additional information needed:
  - CWSU meteorologists stated:
    - Smaller time frames are needed, rather than having a 24 hour smear, suggested:
      - 6 hour time frames
      - 2 to 3 hour time frames which would match up with the TCF
      - 1 hour or less
    - The capability to zoom into specific regions.
    - Provide echo tops up to 25,000 and 35,000 feet.
  - NAMs stated the need to have wind and lightning information.

Question 2

The current graphic covers a 24hr period (9Z to 9Z). Would smaller time windows be useful? Over what time frame would probabilistic information of this type be useful (e.g. days 3 to 5)?

- CWSU meteorologists:
  - 12 out of 15 stated the 24 hour time frame would be useful.
  - 3 out of 12 stated the need to have the 24 hour timeframe to continue out 3-5 days.
    - 6 out of 12 would prefer 6 hour time bins in addition to the 24 hour time frame.
    - 6 out of 12 would prefer 2 to 3 hour time bins to match up with the TCF in addition to the 24 hour time frame.
  - 3 out of 15 stated the 24 hour time frame would not be useful and would prefer 30 min to 1 hour time updates.
- FAA PERTI stated the 24 hour product updating twice a day would be useful for planning and would want the product to go out 3 to 5 days.
- The Weather Research and Development engineer stated the 24 hour graphic was useful.
- The FAA program manager/former CWSU meteorologist stated 2 to 3 hour updates to match the TCF would be useful.

Question 2 (Continued)

- National Aerospace Meteorologists (NAM)
  - 1 out of 2 NAMs stated the 24 hour update was useful, but would prefer the timeframe to go out 2 to 4 days.
  - 1 out of 2 NAMs stated a preference to have a maximum of a 3 hour timeframes with a preference for 1 hour timeframes.

Question 3

The "Exceedance Probabilities" provides probabilities for either a 25%, 50%, or 75% likelihood a TCF polygon will be created. Are these probabilities adequate for extended range planning? What probability thresholds are deemed impactful for your planning/forecasting considerations? (e.g. 25%, 50%, 75%; 30%, 60%, 90%...). Are the colors used adequate and easy to distinguish?

- 14 out of 15 CWSU participants stated the thresholds 25%, 50%, and 75% were adequate.
- 1 CWSU participant stated additional probabilities every 10% would be beneficial, but the models might not be able to be able to support/verify thresholds with that frequency.
- NAM, PERTI, FAA and Weather Research Engineer Participants stated the thresholds 25%, 50%, and 75% were adequate.
- Participants stated when the likelihood of convection occurring is at 50%, further investigation, analysis, and monitoring will occur.

Question 3 (Continued)

- Participants stated confidence would increase of convection occurring when the probability is at 75%.
- Participants stated the colors used for the probability thresholds are adequate and easy to distinguish.
- However, one participant stated the colors may be difficult to distinguish for color blind users.

Question 4

How would you use the Probabilistic TCF product (alongside which other products)? Would the probability information add value to the decision making process compared to other products such as the TCF/eTCF?

- CWSU meteorologists would use the Probabilistic TCF:
  - To produce briefings.
  - Alongside other convective forecasts to aid in determining validity.
  - Would use HRRRe and HREF and other ensemble models to develop a detailed convective forecast.
- NAMs would use the Probabilistic TCF alongside other convective forecasts such as: Convective Allowing Model (CAMs), National Blend of Models (NBM) and Model-based fault diagnosis (MBFD).
- PERTI team would use the product along side the Aviation Weather products such as winds, terminal area forecasts, TCF, ECFP and significant meteorological information (SIGMET).
- All participants would use the Probabilistic TCF to identify focus areas.

Question 4 (Continued)

- Probability thresholds for decision making
  - All participants stated the thresholds 25%, 50%, and 75% were adequate.
  - All participants agreed the probability information would add value to the decision making process.
  - Thresholds at 50% would provide an indication the weather has to be monitored and further investigation, using other sources, is necessary to determine if the weather will have an impact on traffic.
  - Thresholds of 75% or greater would provide a high likelihood that traffic impacts will occur due to weather, therefore, plans for reroutes or deviations may start to occur.
- The probability information provides confidence in decision making.

Question 5

Does probabilistic information specific to TCF criteria add value over more general convective probability information as seen in ECFP?

- All participants stated the TCF criteria added value over more general convective probability information.
- CWSU meteorologists and Former CWSU meteorologist
  - 9 out of 16 would use the Probabilistic TCF alongside the ECFP.
  - 5 out of 16 would replace the ECFP with the Probabilistic TCF.
  - 2 out of 16 did not have enough knowledge of the ECFP or did not feel comfortable answering the question.
- Both NAMs would replace the ECFP with the Probabilistic TCF.
- One PERTI team member would use the Probabilistic TCF alongside the ECFP and the other did not have enough knowledge of the ECFP or did not feel comfortable answering the question.
- The Weather Research and Development Engineer did not have an opinion on this question.

Question 6

When comparing the HREF and HRRRe guidance did one seem to provide more useful information? Are there events or situations when the HREF or HRRRe would be used over the other? If so, what are those events/situations?

- The HREF and HRRE guidance provide useful information such as having the capability to see the spread between the ensemble members.
- Participants stated the need to know how the models are validating on the previous days to determine which model guidance to use.
- HREF tends to over predict the forecast and HRRRe tends to miss some of the sparse coverage areas.
- Personal preference on which model to use based on familiarity with the model, current situation of weather and air travel, and recent model performance.

Note: Due to the HRRRe being unavailable during a portion of the experiment or the participant having time restraints, some participants had a limited response.

Question 7

Does providing the option to overlay the Final TCF/eTCF Polygons (Sparse, Medium, and All) on the probabilistic information add value for decision making? Are other overlay options needed? Are the polygon colors easy to distinguish?

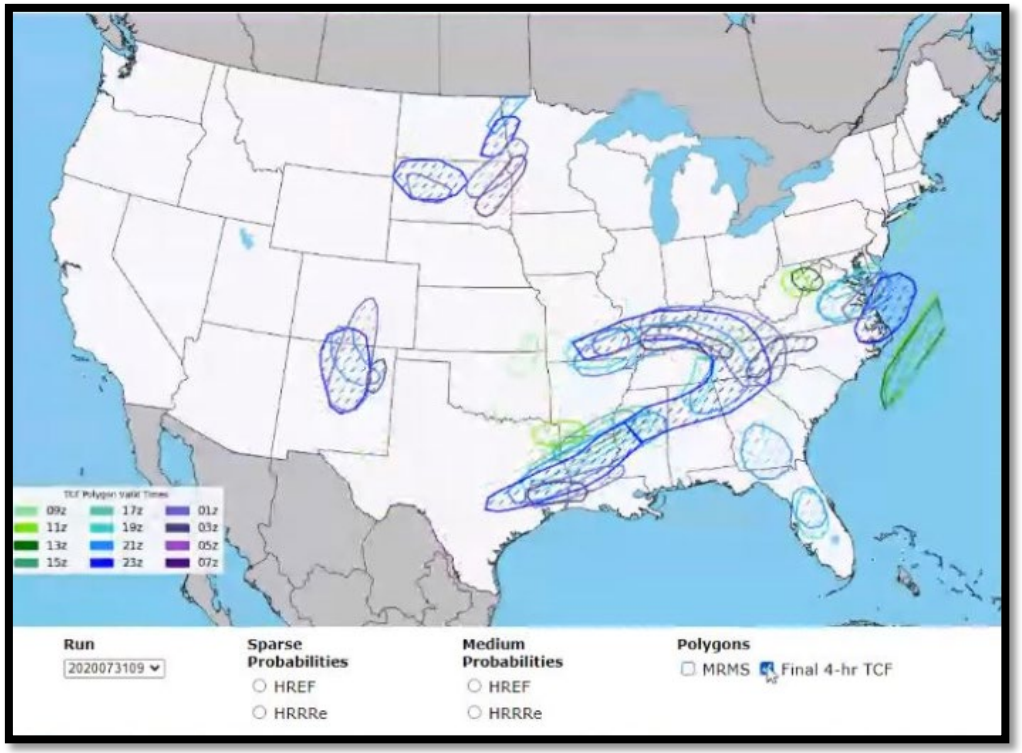
- All participants stated the capability to overlay the final TCF polygons and Multi-Radar Multi-Sensor (MRMS) data would provide value for decision making.
- The capability to overlay the final TCF polygons and MRMS data would increase confidence in decision making.
- Final TCF polygons and MRMS data would be useful for validating model performance.

Question 7 (Continued)

- Additional overlays requested by participants:
  - ATRCC boundaries
  - Echo top heights specifically thresholds at 25000 and 3500 feet.
  - Wind
  - Lightning
  - Hail and other weather hazards
  - Impact based graphics
  - Major airports
  - METAR locations
  - TRACONs
  - Storm motion
  - Main fixes and routes

Question 7 (Continued)

- Additional overlay comments:
  - Graphic can become cluttered with polygons making the information difficult to interpret. See the figure to the right.
  - Need the option to be able to turn off/on time stamps to see specific times and declutter the graphic.
- Participants found the polygon colors easy to distinguish with the following recommendations:
  - Use different color schemes to distinguish. between MRMS and final TCF polygons.
  - Use a greater contrast between colors in polygons.



Screenshot of participant screen displaying cluttered polygons.

Question 8

Would the Probabilistic TCF product be used in the daily PERTI briefings? If not why? If yes, how would the Probabilistic TCF be incorporated into the briefings? Do you need the capability to put into a briefing? What graphics do you need to put into a briefing?

(Note: This question was only asked to the two PERTI participants.)

- The Probabilistic TCF provides a good overview of convective areas for briefings.
- Having the option of using HREF and HRRRe is useful for strategic planning.
- The Probabilistic TCF needs echo top information starting at 1,800 feet, increasing by 6,000 feet up to 42,000 feet.
- Participants stated a need for additional information such as lightning and winds.

Conclusions and Recommendations

Objective 1

Determine the suitability of a probabilistic summary of convective threats for a 24 hour time period based on TCF criteria.

- The Probabilistic TCF product would provide an adequate 24 hour snapshot to identify areas with a likelihood of convection occurring.
- The Probabilistic TCF product is useful for identifying convective areas to aid in strategic planning.
- The graphic provides a useful “quick glance” to determine areas of TCF exceedance.

Objective 2

Determine how to design the Probabilistic TCF product including:

- **Determining information needed for decision making.**
- **Determining how to present probabilistic information for decision making.**

- Participants stated the 24 hour probabilistic forecast was useful, although some participants preferred the forecast to be broken down into smaller time frames.
- Participants found the ability to overlay MRMS/final TCF polygons a useful tool to validate the Probabilistic TCF forecast.
- Participant stated the 25%, 50%, and 75% thresholds were acceptable and further investigation would occur at 50% probability and action on a 75% probability.
- Participants agreed the colors used in the Probabilistic TCF were acceptable, but suggested using more contrast between colors for the TCF polygons.
- Additional overlays, such as ARTCC boundaries, echo tops, major airports, satellite imagery, radar data, and jet routes, would be beneficial.

Objective 3

Determine user preference for model guidance performance.

- Participants found it useful see the spread in the model guidance ensemble members.
- Participant preference would be determined by how each model validated in previous days.
- Overall consensus is that the HREF tends to over predict the forecast and HRRRe tends to miss some of the sparse coverage areas.

Recommendations

- Add the ability to zoom into specific geographic areas.
- Instead of a 24 hour timeframe recommend using:
    - 6 hour time frames,
    - 2 to 3 hour time frames which would match up with the TCF, and/or
    - 1 hour or less.
- Provide a feature which allows meteorologists to toggle on and off specific MRMS and final TCF polygons by time and location.
- Provide the capability to overlay ARTCC boundaries, lightning, winds, major airports, radar and satellite data, and jet routes.