Aviation Weather Probabilistic and Confidence Messaging

Southwest Aviation Weather Safety Workshop (SAWS)

April 22, 2023

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My Background

MISSISSIPPI STATE UNIVERSITY

Objectives

- What is probabilistic and confidence messaging?
- Why probabilistic and confidence messaging for aviation?
- How can we be confident in embracing uncertainty?
- How are probabilistic forecasts applied to aviation decision making?
- How does this type of messaging impact the aviation mission?

Please Note

- Probability and confidence messaging for aviation is a new endeavor for the NWS in terms of application.
- The transition to this method will take some time.
- This presentation hopes to bring awareness to the direction that the National Weather Service is headed.

What is Probabilistic and Confidence Messaging?

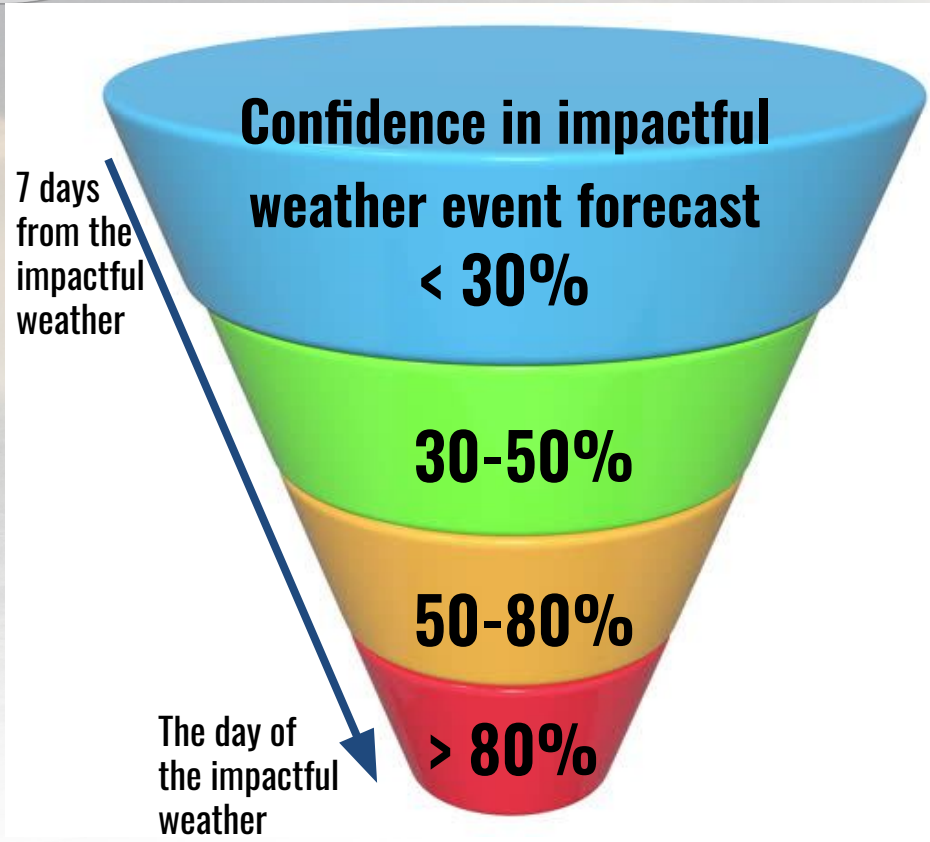
A method of conveying weather forecast information in terms of forecast probability and Meteorologist confidence in the forecast.

The Deterministic Messaging Approach

- Messaging a deterministic value, provides a false sense of confidence.
  - ‘Snowfall will begin, Sat 14 Jan 2023 / 06Z, and continue through, Sat 15 Jan 2023 / 00Z, with 1 inch of total snow expected.’

Four-Tiered Probabilistic Messaging Strategy

weather.gov/



< 30% (Approximately 6 to 7 days out)

-Broad-brushed graphics stating what we know and don't know

30-50% (Approximately 4 to 5 days out)

-Probability graphics showing chances of a certain amount of snow or other impactful weather

50-80% (Approximately 24 to 72 hours out)

-Probability graphics and confidence information in reference to snow amounts

-Snow start/stop

-TAF period begins

> 80% (Within 24 hours)

-Probability graphics and confidence information in reference to snow amounts

-Snow start/stop and freezing precipitation

-TAF period

Why Probabilistic and Confidence Messaging for Aviation?

Numerical Weather Prediction (NWP):

- Numerical model ensembles - Make it possible to obtain mathematical solutions resulting from the input of many numerical model forecasts.
  - Probability of occurrence, magnitude or timing of an event.
  - Probability analysis informs Meteorologist forecast confidence.

Value to Aviation

"First, it should be understood that forecasts possess no intrinsic value. They acquire value through their ability to influence the decisions made by the users of the forecasts." (Murphy, Weather and Forecasting 1993)

The National Weather Service Mission:

"Provide weather, water and climate data, forecasts, warnings, and impact-based decision support services for the protection of life and property and enhancement of the national economy."

Weather Prediction Uncertainty

- Weather forecast uncertainty has been studied for a long time:
  - *Deterministic Nonperiodic Flow.* (Lorenz, 1963)
  - *General Circulation Experiments with the Primitive Equations. 1. The Basic Experiment.* (Smagorinsky, 1963)
  - *Stochastic Dynamic Prediction.* (Epstein, 1969)
  - *Atmospheric Predictability as Revealed by Naturally Occurring Analogues.* (Lorenz, 1969)
  - *Theoretical Skill of Monte Carlo Forecasts.* (Leith, 1974)
- Research conclusions show that forecast error is inevitable.

Social Science Research on Forecast Messaging

Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts (NRC 2006)

"...no forecast is complete without a description of its uncertainty."

Research:

- Joslyn, S. L., & LeClerc, J. E. (2012). Uncertainty forecasts improve weather-related decisions and attenuate the effects of forecast error. *Journal of Experimental Psychology: Applied, 18*(1), 126–140. https://doi.org/10.1037/a0025185
- Grounds, M. A., & Joslyn, S. L. (2018). Communicating weather forecast uncertainty: Do individual differences matter? *Journal of Experimental Psychology: Applied, 24*(1), 18–33. https://doi.org/10.1037/xap0000165
- Margaret A. Grounds, Susan Joslyn, Kyoko Otsuka, "Probabilistic Interval Forecasts: An Individual Differences Approach to Understanding Forecast Communication", *Advances in Meteorology*, vol. 2017, Article ID 3932565, 18 pages, 2017. https://doi.org/10.1155/2017/3932565
- Budescu, D., Por, HH., Broomell, S. *et al.* The interpretation of IPCC probabilistic statements around the world. *Nature Clim Change* 4, 508−512 (2014). https://doi.org/10.1038/nclimate2194
- Sarah C. Jenkins, Adam J. L. Harris & R. Murray Lark (2019) When unlikely outcomes occur: the role of communication format in maintaining communicator credibility, Journal of Risk Research, 22:5, 537-554, DOI: 10.1080/13669877.2018.1440415
- Lenhardt, E. D., R. N. Cross, M. J. Krocak, J. T. Ripberger, S. R. Ernst, C. L. Silva, and H. C. Jenkins-Smith, 2020: How likely is that chance of thunderstorms? A study of how National Weather Service forecast offices use words of estimative probability and what they mean to the public. J. Operational Meteor., 8 (5), 64-78, doi: https://doi.org/10.15191/nwajom.2020.0805

The Need to Quantify Uncertainty

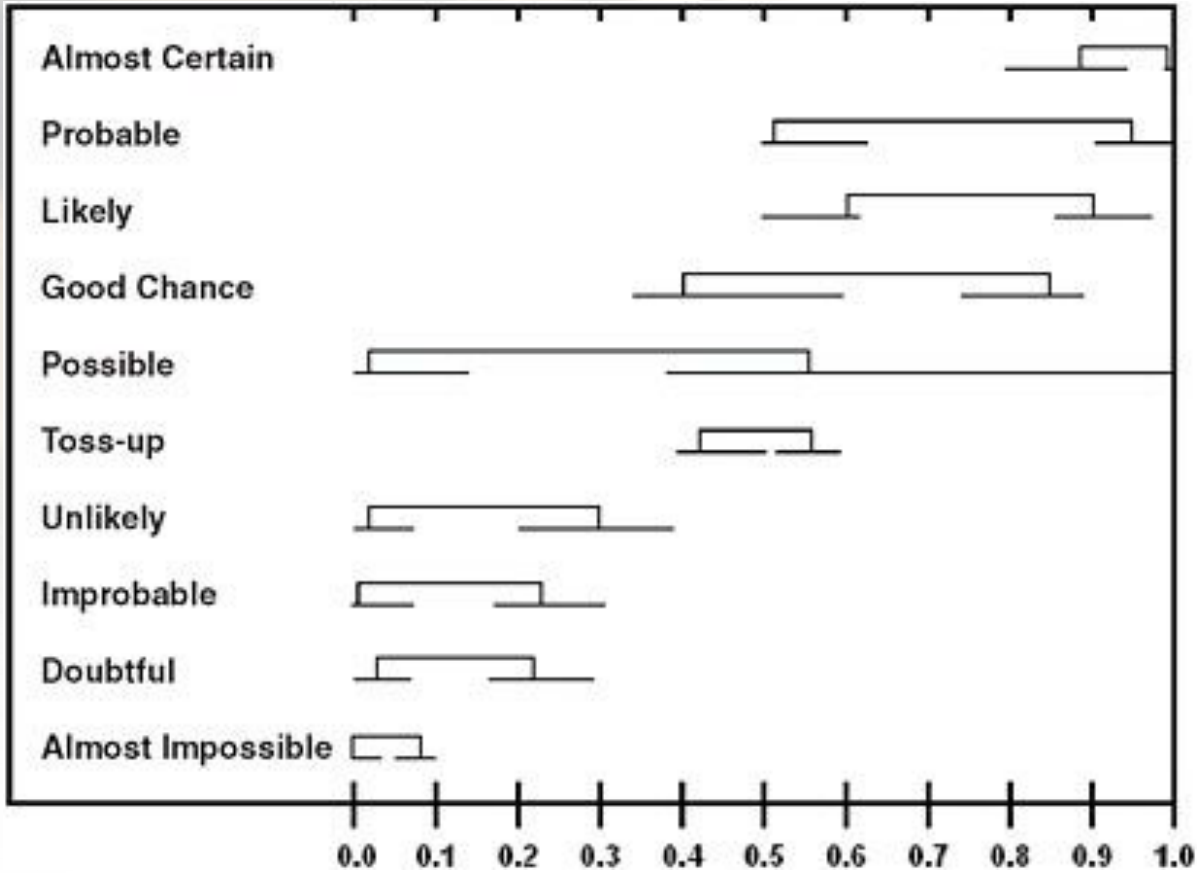


Figure 2.5: Range of interpretations of different verbal uncertainty terms. (Wallsten et al, 1986)

Social Science Research Forecast Messaging Recommendations

- **Use probability information in place of deterministic statements in forecasts.** (Joselyn and LeClerc, 2012); (Grounds and Joselyn, 2018)
- **Use numeric point estimates if they are available and appropriate; if they are not, use numeric probability ranges or predictive intervals to emphasize uncertainty.** (Grounds et al, 2017); (Lohre et al, 2019)
- **Include numeric translations next to words/phrases that indicate probability information.** (Budescu et al, 2014)
- **If comprehension of probability information is especially important, use numeric probabilities alone or first (before words/phrases).** (Jenkins et al, 2019)
- **When using words and phrases to communicate probability information, include rank adjectives (like low, medium, and high) to indicate the magnitude of the probability; this is especially important if numeric translations are not available.** (Lenhardt et al, 2020)

The Value of Probabilistic and Confidence Messaging to Aviation

Research shows that such information is:

- Received with more consistent understanding.
- Processed more accurately.
- And that people tend to make the decisions that result in the most positive outcomes when presented with probabilistic and confidence messaging.

This is where the value of the forecast is realized:

"First, it should be understood that forecasts possess no intrinsic value. **They acquire value through their ability to influence the decisions made by the users of the forecasts."** (Murphy, Weather and Forecasting 1993)

How Can We be Confident in Embracing Uncertainty?

- Social science research tells us that this is the best way forward.
- Advanced Numerical Weather Prediction (NWP) makes it possible.

How Are Probabilistic Forecasts Applied to Aviation Decision Making?

Kathryn's Report: More private pilots heading to Bozeman, Gallatin County, Montana, Sat 9 Jan 2016.

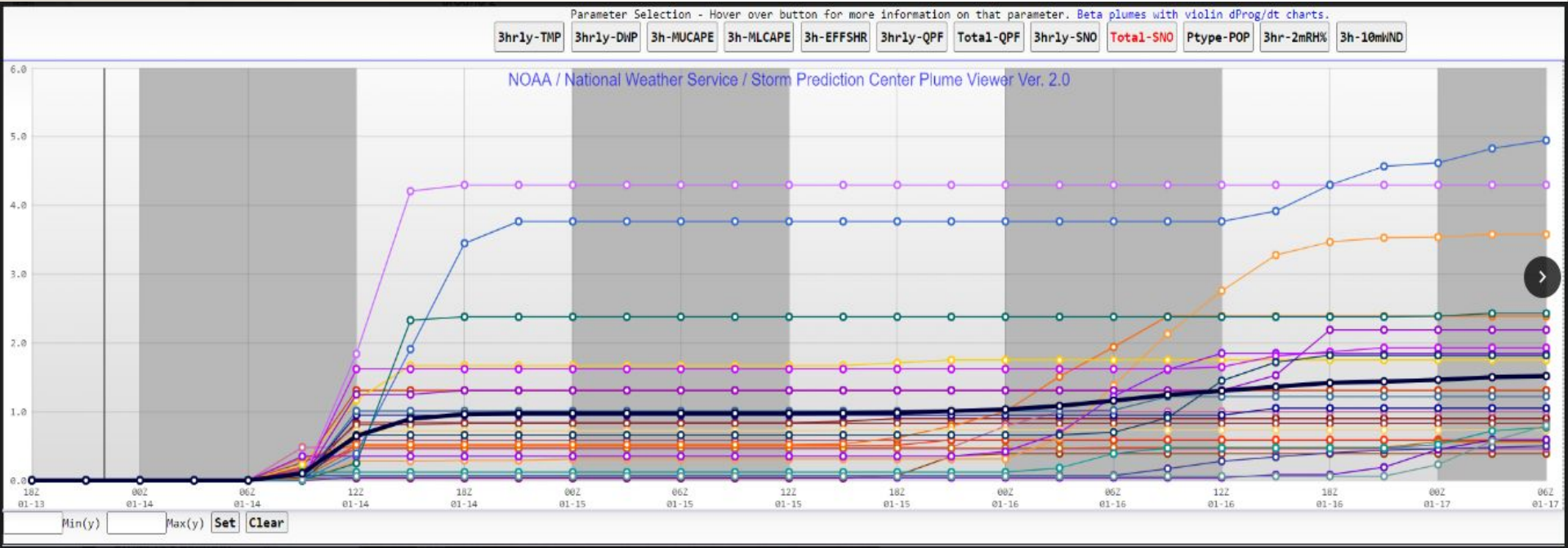
Airfield Management

- The team of Meteorologists at NWS Great Falls (Team TFX), has partnered with Helena Regional Airport (Team KHLN) to experiment with probabilistic and confidence messaging as it applies to Airfield Management.
- The following slides include examples from this joint effort.

The Truth of Uncertainty

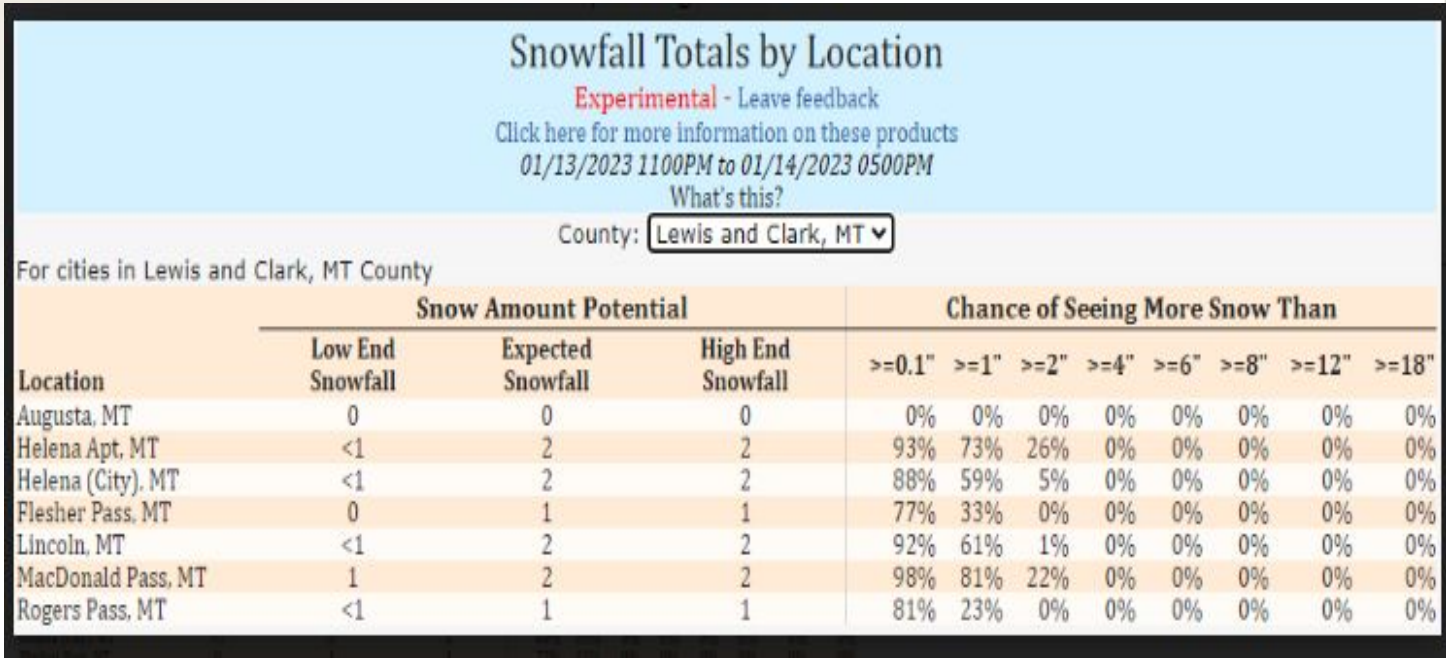
- The greater accuracy comes in expressing the truth of uncertainty.

13 Jan 2023 / 16L: Here is a model plume of potential snow totals from our most aggressive set of models, showing the potential for as much as 4" of snow, but with the vast majority of model solutions depicting less than 1" of snow.



Precision of Language

- There is high confidence in the following forecast.
- For the period of Sat 14 Jan 2023 / 06Z thru Sun 15 Jan 2023 / 00Z snow amount probability is as follows:
  - >= 1”, 73%
  - >= 2”, 26%
  - >= 4”, 00%



Snowfall Totals by Location

Experimental - Leave feedback

Click here for more information on these products

01/13/2023 1100PM to 01/14/2023 0500PM

What's this?

County: Lewis and Clark, MT

For cities in Lewis and Clark, MT County

Location	Snow Amount Potential			Chance of Seeing More Snow Than							
	Low End Snowfall	Expected Snowfall	High End Snowfall	>=0.1"	>=1"	>=2"	>=4"	>=6"	>=8"	>=12"	>=18"
Augusta, MT	0	0	0	0%	0%	0%	0%	0%	0%	0%	0%
Helena Apt, MT	<1	2	2	93%	73%	26%	0%	0%	0%	0%	0%
Helena (City), MT	<1	2	2	88%	59%	5%	0%	0%	0%	0%	0%
Flesher Pass, MT	0	1	1	77%	33%	0%	0%	0%	0%	0%	0%
Lincoln, MT	<1	2	2	92%	61%	1%	0%	0%	0%	0%	0%
MacDonald Pass, MT	1	2	2	98%	81%	22%	0%	0%	0%	0%	0%
Rogers Pass, MT	<1	1	1	81%	23%	0%	0%	0%	0%	0%	0%

Precision of Language

Helena Aviation Partner Email Notification

National Weather Service - Great Falls

Issued: 456 PM, Sunday, January 22, 2023
Point of Contact: NWS Operations (24/7/365) (406) 952-3790

KEY POINTS

- A quick yet impactful round of snow is expected Monday afternoon

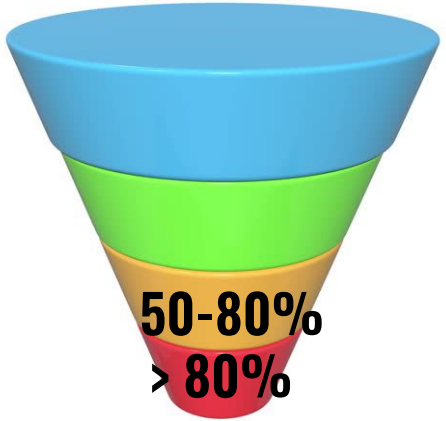
DETAILS AND CONFIDENCE

Helena Regional Airport (KHLN)

Forecast Details:

- ***Estimated Start Time:*** 1-3 PM MST Monday
- ***Estimated End Time:*** 4-6 PM MST Monday
- ***Estimated Snow Accumulation:*** T - 1"
- ***Freezing Rain/Ice Possible:*** No

Probability for >0.1" snow accumulation: 80%
Probability for >1.0" snow accumulation: 27%
Probability for >2.0" snow accumulation: 2%



Guidance for issuing this product

- 1 inch of snowfall forecast in the KHLN nearby mountains
- 0.5 inches of snowfall at Helena Regional Airport
- When the above mentioned criteria is forecast to occur within the next 48 hours
- Updated twice per day
  - If the forecast changes
  - If value can be added

Aviation Operations

```
.AVIATION...
522 PM MST Tue Jan 17 2023 (18/00Z TAF Period)

KHVR:

The first few hours of this TAF period are characterized by
predominant MVFR condition and intermittent IFR conditions in light
snow and mist and with low ceiling. From 08/03Z skies scatter-out
and clear, allowing for surface cooling. There is moderate to high
confidence in the development of LIFR conditions in fog with
vertical visibility conditions. Winds remain light and variable
through 18/14Z, at which point winds become southwesterly at 9KT.
These southwesterly winds are expected to be just strong enough to
aid in the dissipation of fog/mist, allowing conditions to become VFR
and remain VFR through the remainder of the TAF period. Expect
mountain obscuration.

KCTB, KGTF, KLWT, KHLN, KBZN, KEKS:

VFR conditions are forecast for these airfields throughout this TAF
forecast period. Near MVFR conditions are expected due to low
ceiling. Ceilings slowly increase throughout the period. Expect
mountain obscuration. Confidence is moderate to high in
southwesterly to west southwesterly winds strong enough to inhibit
the formation of fog/mist. Periods of breezy to gusty winds are
forecast for KCTB and KGTF. Southerly breezy winds develop at KEKS.
In this region, southerly winds, when funneled through north-south
oriented mountain valleys/passes, impact light aircraft operations.
- Fogleman

Refer to weather.gov/zlc for more detailed regional aviation weather
and hazard information.
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- In association with TAF issuance - Aviation Forecast Discussion

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.AVIATION...
525 PM MST Sat Jan 21 2023 (22/00Z TAF Period)

Predominantly, VFR conditions are expected for the duration of this
forecast period, with the exception of KGTF and KBZN, where
predominant MVFR conditions are forecast from 22/19Z. All TAFs
include PROB30 Groups which take conditions into the MVFR/IFR range
in light snow and blowing snow or mist and with low ceiling.
Snowfall spreads across southwest, central and north central
Montana. Expect to encounter mountain obscuration. Gusty to strong
gusty winds are forecast. High Winds are forecast along The
North/South Rocky Mountain Front and the adjacent plains. Much of
the moisture that makes its way toward the surface is evaporated in
winds aloft. Areas of Virga should be expected along with all of the
associated hazards.
- Fogleman

Refer to weather.gov/zlc for more detailed regional aviation
weather and hazard information.
```

Aviation Forecast Discussion Access

aviationweather.gov/taf/board

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NOAA NATIONAL WEATHER SERVICE

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Impacts TAF Board — TAF Home | Plot | Data | Board | Info

FOR SITUATIONAL AWARENESS. NOT TO BE USED FOR FLIGHT PLANNING PURPOSES.

IDs: KGTF Submit

KGTF - Great Falls Intl, MT, US

Issued at 2345 UTC 26 Feb 2020
Updated at 0018 UTC 27 Feb 2020

Potential Impact: None | Slight | Moderate | High

Time	2353Z	27/01Z	27/02Z	27/03Z	27/04Z	27/05Z	27/06Z	27/07Z	27/08Z	27/09Z	27/10Z	27/11Z	27/12Z	27/13Z >>
Type	OBS	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL	PRVL
VIS	10	>6	>6	>6	>6	>6	>6	>6	>6	>6	>6	>6	>6	>6
CIG	90	80	80	80	--	--	--	--	--	--	--	--	--	--
Cover	OVC	BKN	BKN	BKN	SCT	SCT	SCT	SCT	SCT	SCT	SCT	SCT	SCT	SCT
FltCat	VFR	VFR	VFR	VFR	VFR	VFR	VFR	VFR	VFR	VFR	VFR	VFR	VFR	VFR
WX	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WDir	240	260	260	260	250	250	250	250	250	250	250	250	250	250
WSpd	9	11	11	11	9	9	9	9	9	9	9	9	9	9
WGst	--	18	18	18	--	--	--	--	--	--	--	--	--	--

Raw TAF

```
KGTF 262345Z 2700/2724 26011G18KT P6SM SCT050 BKN080
  FM270400 25009KT P6SM FEW045 SCT080
  FM271500 23012G19KT P6SM SCT150
  FM271800 25020G29KT P6SM FEW180
```

Raw METAR

```
KGTF 262353Z 24009KT 10SM BKN090 OVC110 06/M04 A3009 RMK AO2 SLP218 T00561039 10089 20039 55004
KGTF 262253Z 25014KT 10SM CLR 07/M04 A3009 RMK AO2 PK WND 23026/2210 SLP216 T00721039
KGTF 262153Z 24016KT 10SM CLR 08/M04 A3009 RMK AO2 PK WND 25026/2135 SLP217 T00831039
```

METAR Board
Radar Display
Forecast Discussion

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Aviation Forecast Discussions Data — AFD Home | Data Page | Info

Select Site: KTFX - Great Falls MT

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(EXTRACTED FROM FXUS65 KTFX 270007)


Updated 507 PM MST Wed Feb 26 2020 (27/00Z TAF Period)

Low VFR to brief MVFR conditions expected for the eastern part of
the CWA as virga helps moisten the lower levels and drop ceilings,
with a few rain/snow showers possible this evening from KWYS thru
KHVR, including KBZN. Clearing skies spread east tonight, with VFR
for all sites after 06z. Will need to watch for fog formation with
clearing skies and light winds. Gusty west winds tmrw afternoon, but
LLWS doesn't appear likely as of now. Can't rule out some mountain
wave turbulence during the day/evening tomorrow. -Kredensor
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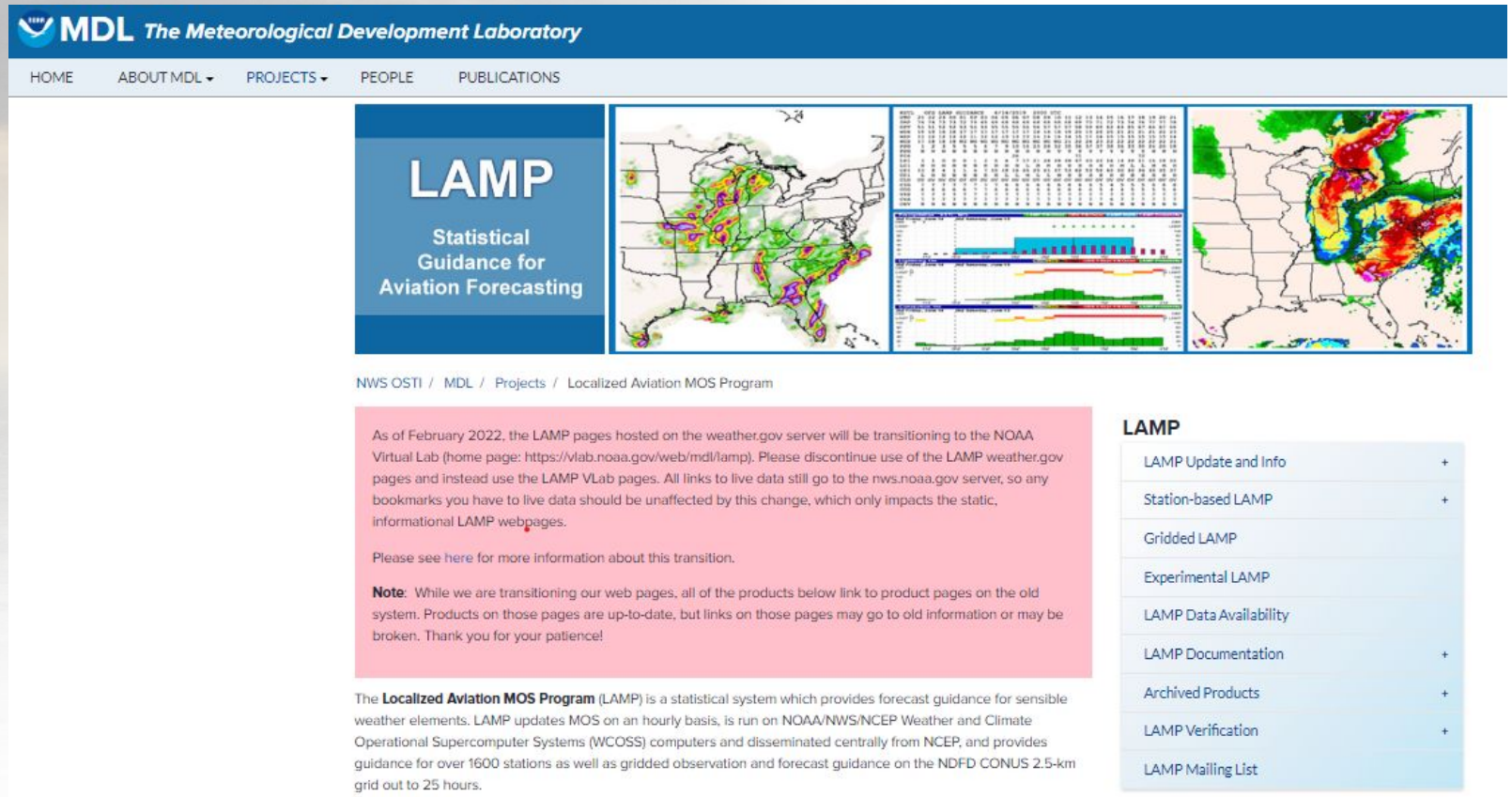
Local Aviation MOS Program (LAMP)

https://vlab.noaa.gov/web/mdl/lamp



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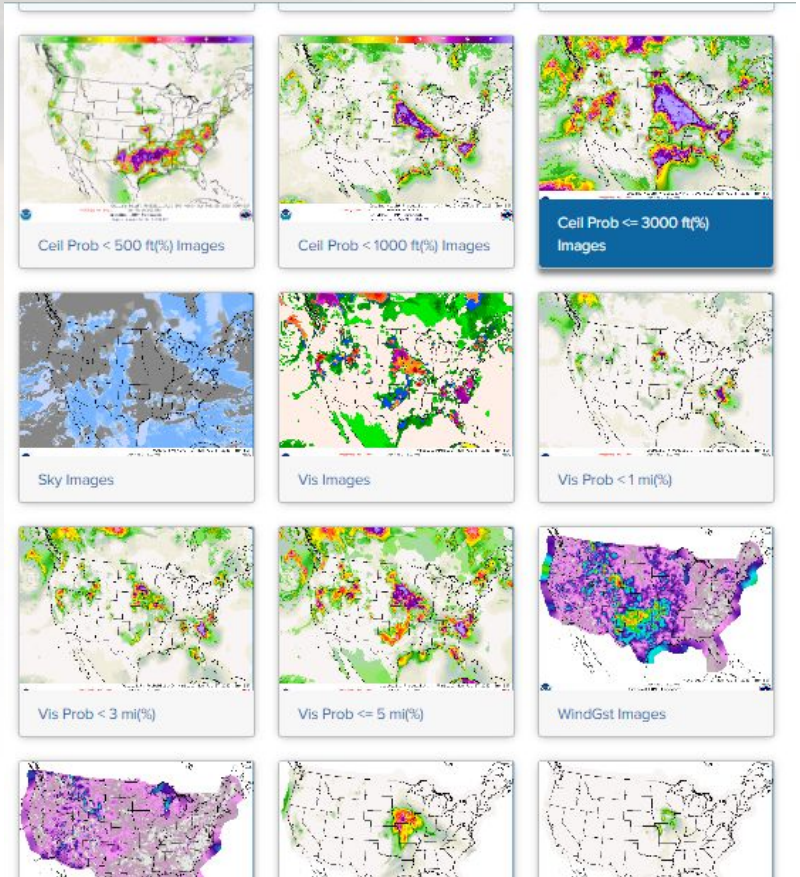
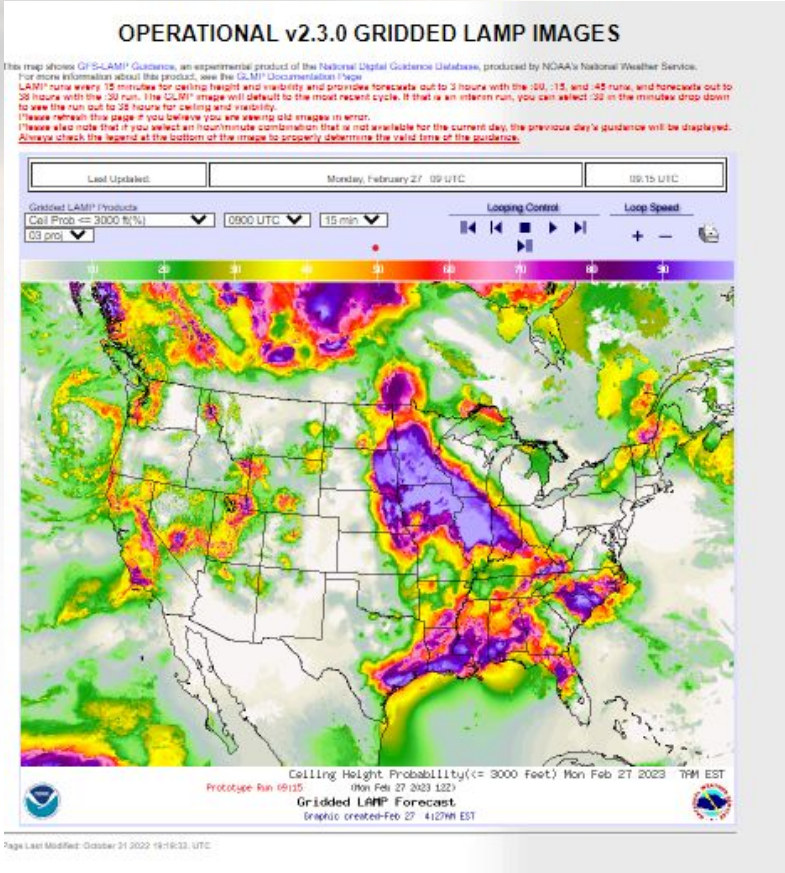


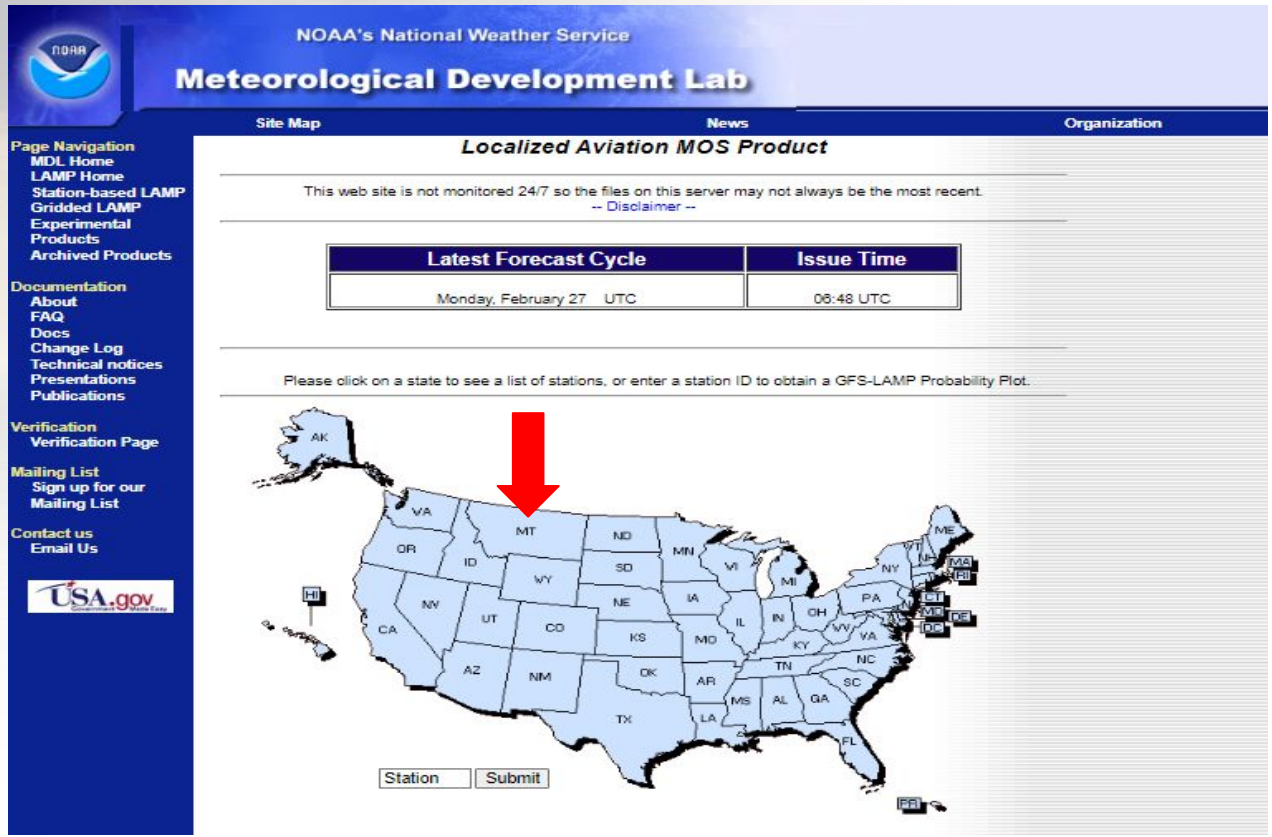
LAMP Probabilistic Gridded Images

https://www.nws.noaa.gov/mdl/gfslamp/glmp.php?&elm=ProbCeil3000



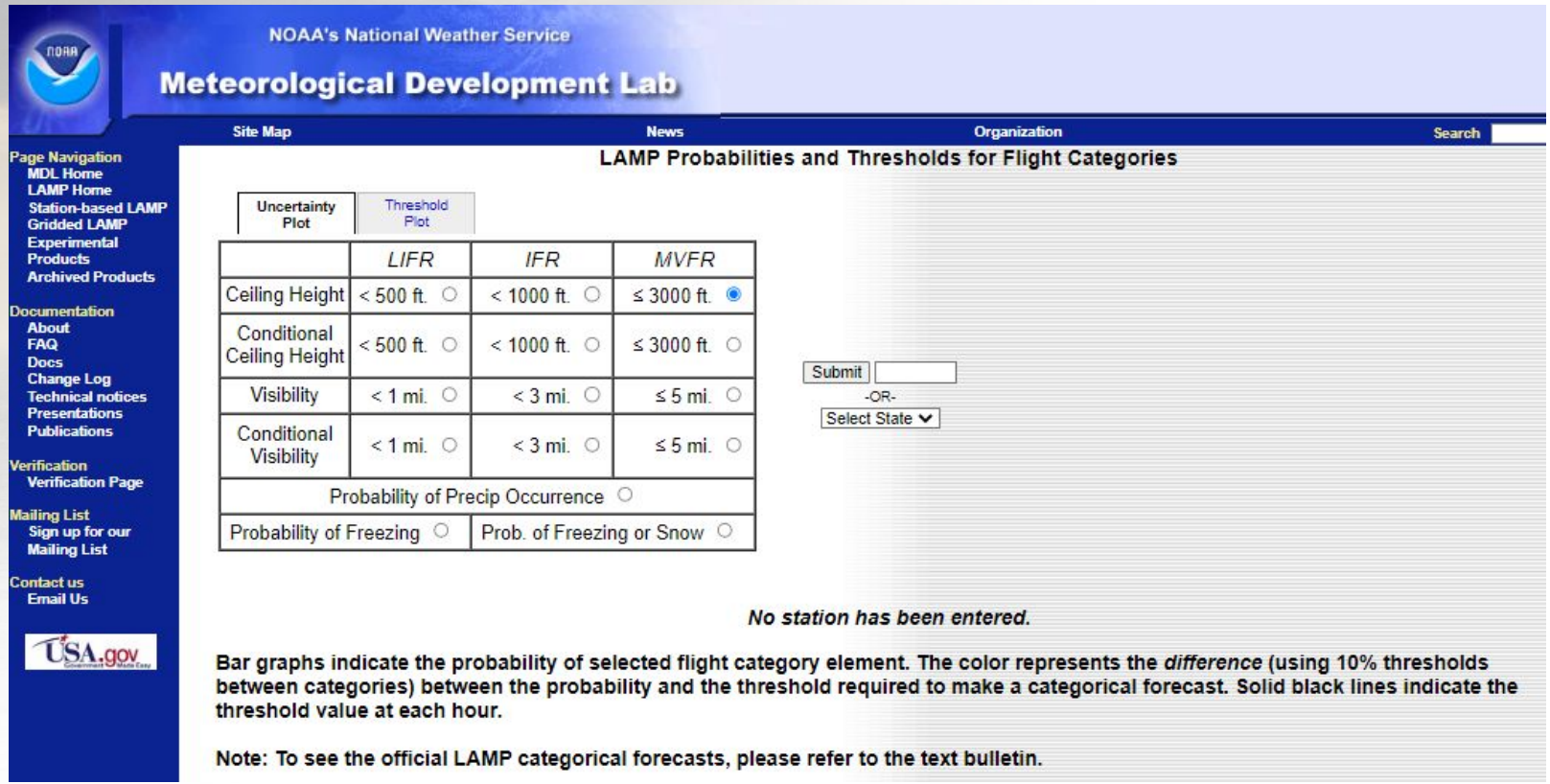
Local Aviation MOS Program (LAMP)

https://www.nws.noaa.gov/mdl/gfslamp/uncertform.php



LAMP Probability Plots

https://www.nws.noaa.gov/mdl/gfslamp/uncertplots.php



LAMP Probability Plots

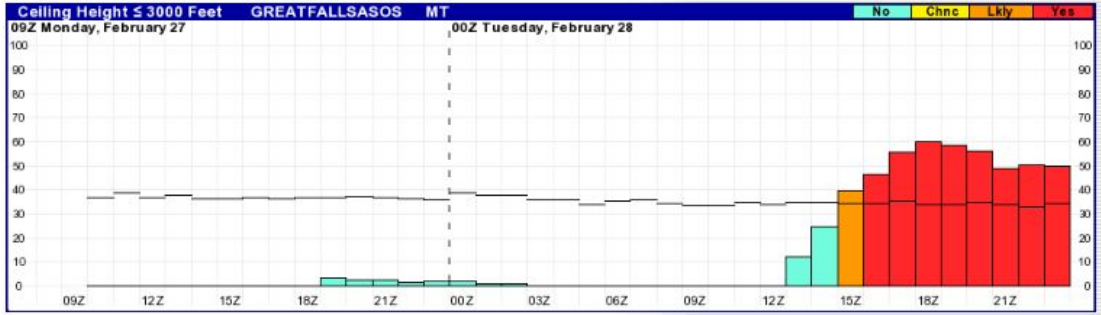
https://www.nws.noaa.gov/mdl/gfslamp/uncertplots.php

LAMP Probabilities and Thresholds for Flight Categories

Uncertainty Plot | Threshold Plot

	LIFR	IFR	MVFR
Ceiling Height	< 500 ft. ○	< 1000 ft. ○	≤ 3000 ft. ◉
Conditional Ceiling Height	< 500 ft. ○	< 1000 ft. ○	≤ 3000 ft. ○
Visibility	< 1 mi. ○	< 3 mi. ○	≤ 5 mi. ○
Conditional Visibility	< 1 mi. ○	< 3 mi. ○	≤ 5 mi. ○
Probability of Precip Occurrence ○			
Probability of Freezing ○	Prob. of Freezing or Snow ○		

Submit KGTF
-OR-
Select State



Bar graphs indicate the probability of selected flight category element. The color represents the *difference* (using 10% thresholds between categories) between the probability and the threshold required to make a categorical forecast. Solid black lines indicate the threshold value at each hour.

How Does This Type of Messaging Impact the Aviation Mission?

Airfield Management/Aviation Operations:

- Enhanced safety
- Economic benefits
- Social benefits
- More efficient and effective planning

Impact Results

"The Helena Regional Airport greatly appreciates the aviation forecasts that are focused on the area surrounding the airport. Having detailed information including the probabilistic forecasting has greatly enhanced our ability to plan for specific airfield snow and ice removal operations to ensure the aviation system remains functional and safe during winter events."

Jeff Wadekamper

Airport Director

Helena Regional Airport Authority

Summary

- What is probabilistic and confidence messaging?
- Why probabilistic and confidence messaging for aviation?
- How can we be confident in embracing uncertainty?
- How are probabilistic forecasts applied to aviation decision making?
- How does this type of messaging impact the aviation mission?

Special Thanks To…

- **Jeff Wadekamper**

  Airport Director

  Helena Regional Airport Authority

Reference

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Questions/Comments/Feedback

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