Providing Probabilistic Ceiling and Visibility Guidance for Enhanced Impact-based Decision Support Services (IDSS)*

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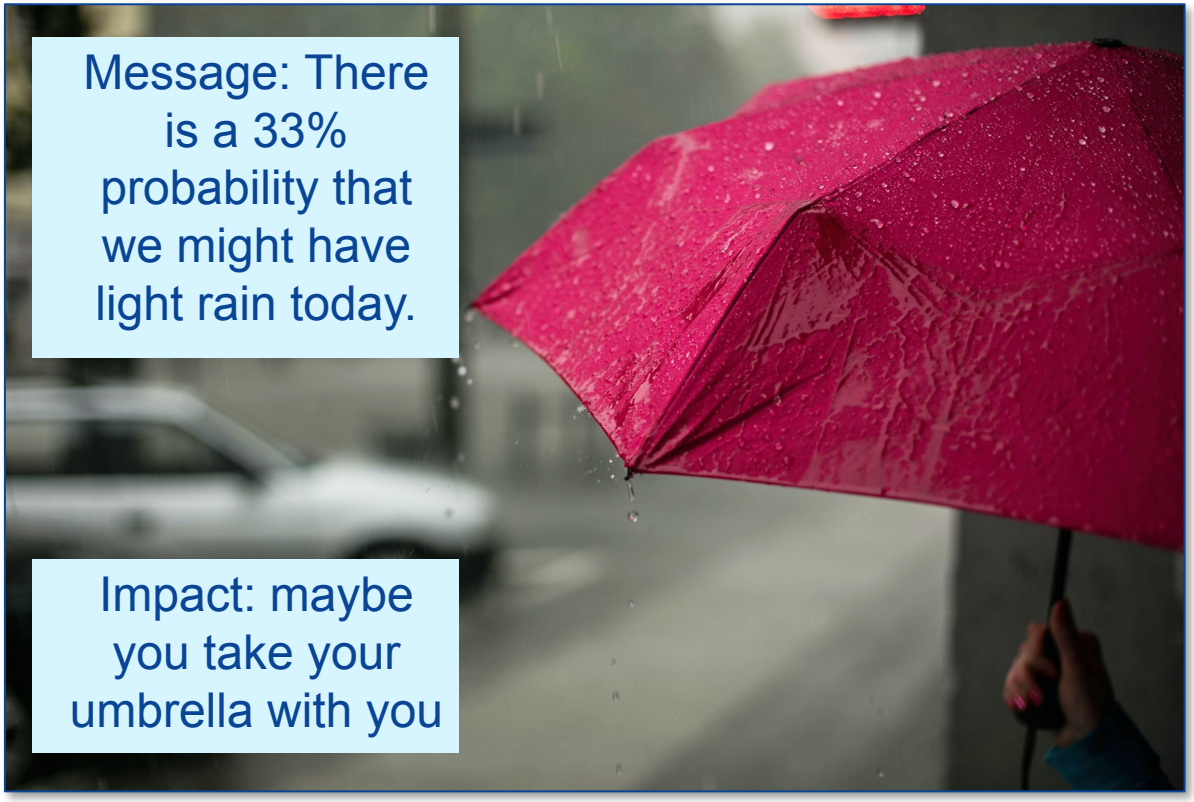
NATIONAL WEATHER SERVICE

* Disclaimer: Portions of this research are in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.

Why Probabilities Matter

- Probabilistic information can help provide Impact-based Decision Support Services (IDSS) for decision makers
  - "…forecasts possess no intrinsic value. They acquire value through their ability to influence the decisions made by users of the forecasts." - Murphy, A. H. (1993). What Is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting, *Weather and Forecasting*, *8*(2), 281-293. Retrieved Dec 23, 2022, from https://journals.ametsoc.org/view/journals/wefo/8/2/1520-0434_1993_008_0281_wiagfa_2_0_co_2.xml

Why Probabilities Matter – low impact



Why Probabilities Matter – high impact

There is a 33% probability that the ceiling of this room will fall in today.

Impact: no one would be here!!

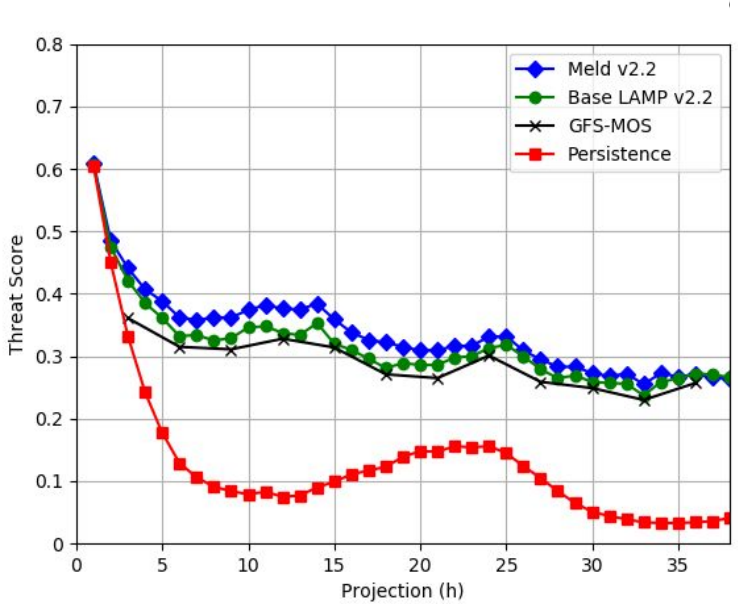
Why Probabilities Matter – for C&V

- Per NTSB data from 2011-2020: “The proportion of Part 91 accidents that resulted in a fatality was 18%; while fatal IMC accidents averaged 64%” – Don Eick, NTSB Senior Meteorologist*
  - Statistically calibrated probabilities of ceiling height and visibility below critical levels are important to indicate risk and to influence decisions
- NWS Director Ken Graham’s “10 Ten” Priorities and Action Strategies for the Future include “Probabilistic Forecasting/Hazard Services”

* Source: July 13, 2022 presentation at the NCAR Aviation Weather Technical Exchange Meeting, Boulder, CA

LAMP Background

- The Localized Aviation MOS Program (LAMP) produces objective guidance based on the statistical interpretation of observations, MOS output, and model output (such as HRRR) through multiple linear regression techniques
- All LAMP deterministic, categorical guidance has underlying calibrated probabilities
- For ceiling height and visibility
  - LAMP guidance covers the short-range period of 1-38 hours
  - LAMP runs in operations:
    - every hour out to 38 hours
    - every 15 minutes out to 3 hours
  - LAMP forecasts are valid at the top of the hr



LAMP/Gridded LAMP 15-minute High Impact Weather for Ceiling & Visibility

15-minute LAMP/GLMP out to 6 hours

- Project funded by FAA Aviation Weather Research Program (AWRP) for Clouds & Visibility to increase the temporal resolution of Gridded LAMP ceiling height and visibility (C&V) guidance from 1 hour to 15 minutes in the first 6 hours of the forecast period.

- Helicopter Emergency Medical Services (HEMS) operators use the NWS Aviation Weather Center (AWC) HEMS Tool* which uses GLMP data to update every 15 mins with latest observational data and forecast data.
  - Providing updated GLMP guidance for C&V every 15 mins for 15-min periods (instead of valid at the top of the hour) will help fill gap in the HEMS tool.

- Will be available at CONUS stations and grid

- High Impact Weather (HIW) C/V Predictand is defined as lowest C/V observed over a 15-minute period ending at HH:14, HH:29, HH:44, and HH:59.

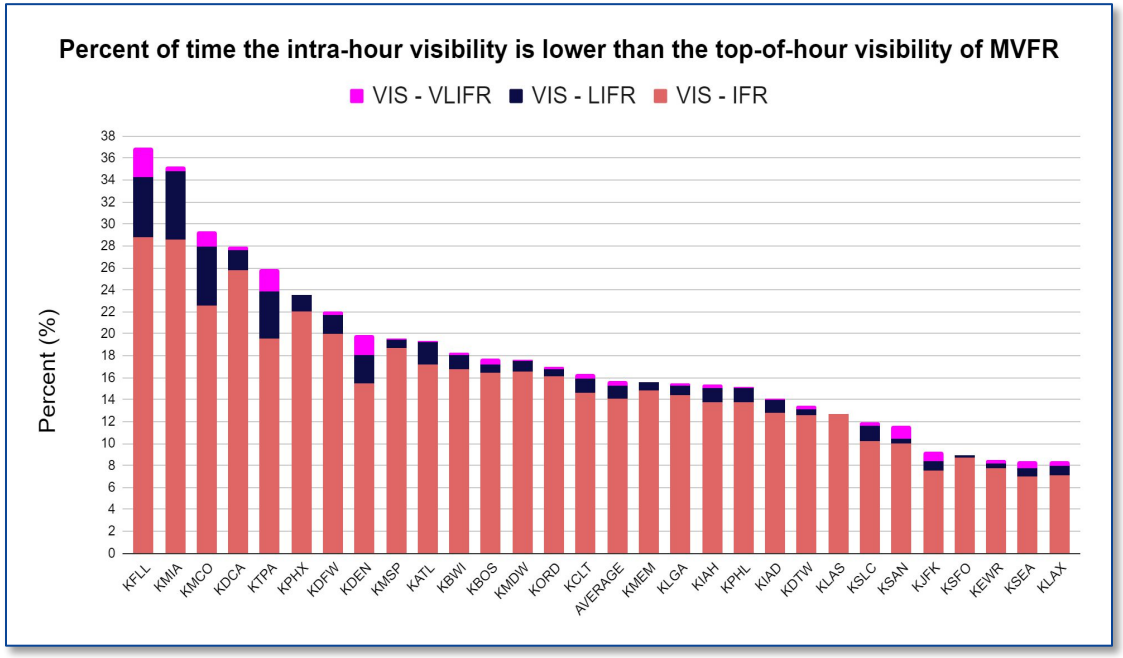
*The HEMS tool is planned to be renamed as the Graphical Forecast - Low Altitude (GFA-LA)

Sub-hourly High Impact Weather

How often do top of hour observations miss impactful events during the hour?

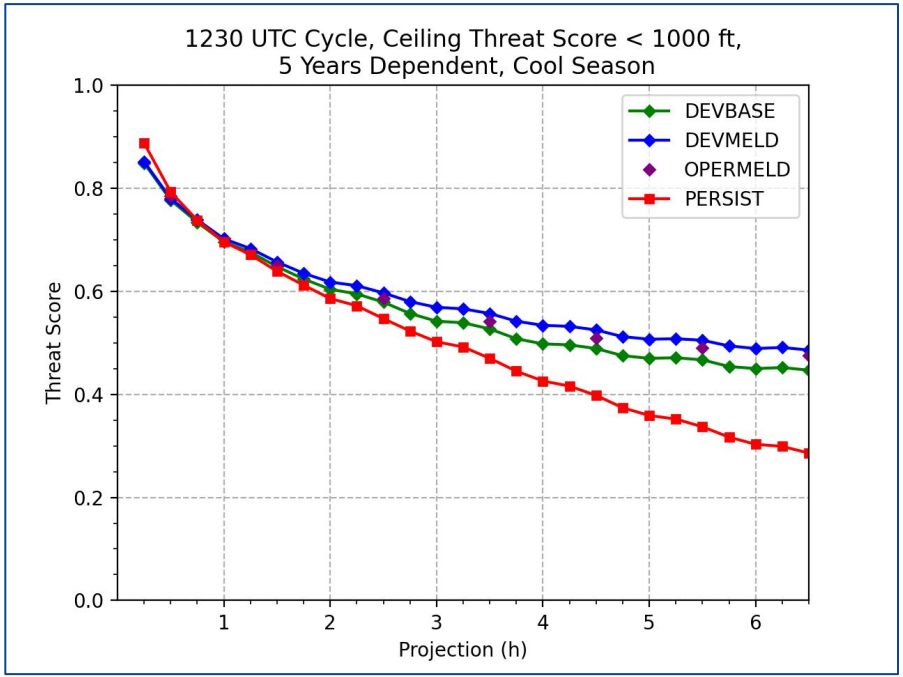
- Intra-hour variability higher for visibility than for ceiling.
- Intra-hour visibility < top-of-the-hour visibility: Max ~37%, average, ~16%.

Visibility

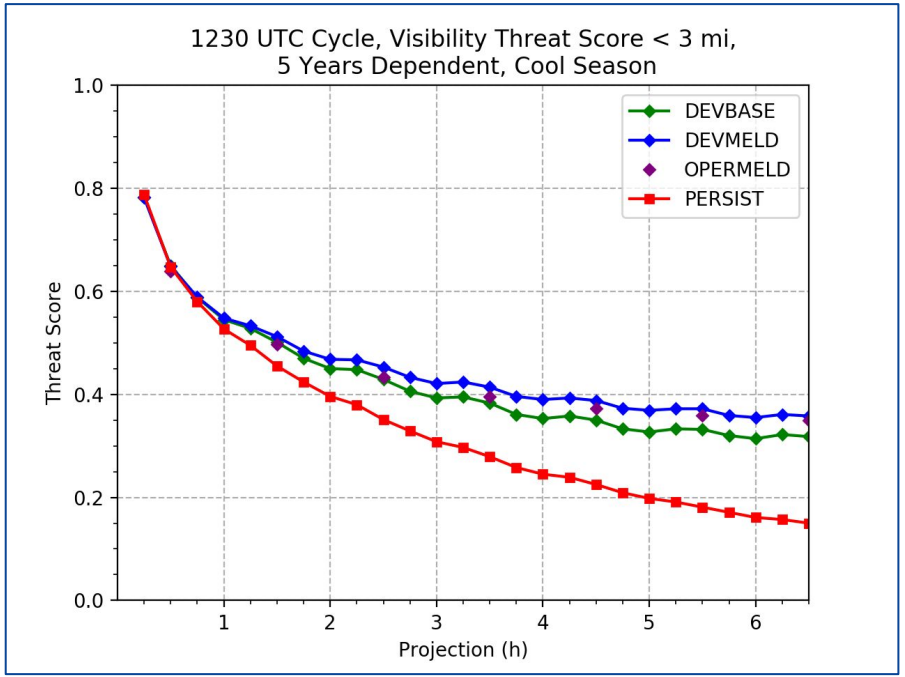


15-min Verification: Cool Season

Ceiling < 1,000 ft



Visibility < 3 miles



New 15-minute station-based LAMP Meld guidance (blue) shows improvement over the new LAMP Base guidance (green), operational hourly Meld (purple), and persistence (red)

LAMP onset/cessation guidance for the Core 30 Airports

LAMP onset/cessation products

- Project funded by FAA AWRP for Clouds & Visibility to create onset/cessation guidance products for use by Traffic Flow Managers. Specific options developed include:
  - A **text product** similar to the operational LAMP text bulletin that displays:
    - Flight Categories (FC) (not currently shown in any LAMP text products)
    - Onset/Cessation of various FCs
    - Probabilities of Ceiling Height and Visibility (currently only shown in LAMP BUFR messages and on LAMP website) corresponding to various Flight Categories
  - A **Webpage product** option

Example of Operational LAMP Text Bulletin

KSFO SAN FRANCISCO GFS LAMP 1630 UTC 7/07/2022

UTC	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
TMP	63	65	66	68	69	70	69	68	66	64	62	60	60	59	59	58	58	58	58	58	58	59	61	63	64
DPT	53	54	54	54	54	54	54	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	54	54	54
WDR	28	28	28	28	28	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	26	27	27	27	27
WSP	15	15	15	17	18	18	18	19	19	18	18	16	15	14	13	12	12	11	11	09	09	09	09	10	12
WGS	20	20	21	23	24	24	25	25	26	25	25	23	21	20	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
PPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PCO	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
P01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PC1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
P06								0						0						0					
LP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LC1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CC1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CLD	OV	BK	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	BK	BK	BK	BK	OV	BK	BK	BK	BK	BK	BK	BK	BK
CIG	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	4	4	4	4	4	4	4	8
CCG	4	4	5	8	8	8	8	8	8	8	8	8	8	5	4	4	4	4	4	3	4	4	4	4	7
VIS	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CVS	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	4	7	6	4
OBV	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Summary of Options

- Numeric Flight Categories / Probabilities
- Letter Flight Categories / Probabilities

FLT	5	4	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	3	3	3	3	3	3	4	4	5	5
FLT	V	M	V	M	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	M	I	I	I	I	I	I	M	M	V	V
CP1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	3	4	4	3	2	1	0	0	0	1	1	1	1	1	1	0	1
CP2	3	5	1	0	0	1	0	0	0	2	4	4	4	5	6	7	8	9	10	13	14	16	16	11	5	10	6	4	8	14	17	15	14	14	13	9	5	6
CP3	5	10	1	3	6	5	0	0	1	2	5	6	6	7	9	10	12	11	11	14	17	19	16	11	5	13	15	18	26	35	44	39	35	30	25	17	10	10
CP4	18	43	35	44	37	34	32	33	32	30	16	15	15	14	13	12	13	11	12	14	17	19	18	14	9	16	22	29	43	58	72	67	65	62	50	38	26	21
VP1	0	0	0	1	1	1	0	1	1	0	0	0	0	1	1	2	2	2	3	4	5	6	8	6	2	1	1	1	1	1	2	2	2	2	1	1	1	1
VP2	1	1	1	2	1	1	0	2	1	1	2	1	2	3	3	3	5	5	5	8	9	11	12	11	5	3	3	3	2	3	4	5	5	4	4	3	3	3
VP3	1	1	1	2	2	1	0	2	2	3	4	4	4	5	5	5	6	7	8	11	13	16	18	17	9	9	11	12	12	15	19	19	15	12	9	6	5	5
VP4	1	1	1	2	2	1	0	2	3	5	6	7	6	7	7	8	9	11	12	16	19	24	27	23	15	16	19	20	22	26	31	30	23	19	15	12	9	8
CPVL	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	3	4	4	3	2	1	0	0	0	1	1	1	1	1	1	1	0	1
CPL	3	5	1	0	0	1	0	0	0	2	4	4	4	5	6	7	8	9	10	13	14	16	16	11	5	10	6	4	8	14	17	15	14	14	13	9	5	6
CPI	5	10	1	3	6	5	0	0	1	2	5	6	6	7	9	10	12	11	11	14	17	19	16	11	5	13	15	18	26	35	44	39	35	30	25	17	10	10
CPM	18	43	35	44	37	34	32	33	32	30	16	15	15	14	13	12	13	11	12	14	17	19	18	14	9	16	22	29	43	58	72	67	65	62	50	38	26	21
VPVL	0	0	0	1	1	1	0	1	1	0	0	0	0	1	1	2	2	2	3	4	5	6	8	6	2	1	1	1	1	1	2	2	2	2	1	1	1	1
VPL	1	1	1	2	1	1	0	2	1	1	2	1	2	3	3	3	5	5	5	8	9	11	12	11	5	3	3	3	2	3	4	5	5	4	4	3	3	3
VPI	1	1	1	2	2	1	0	2	2	3	4	4	4	5	5	5	6	7	8	11	13	16	18	17	9	9	11	12	12	15	19	19	15	12	9	6	5	5
VPM	1	1	1	2	2	1	0	2	3	5	6	7	6	7	7	8	9	11	12	16	19	24	27	23	15	16	19	20	22	26	31	30	23	19	15	12	9	8

Summary of Options (continued)

- One text bulletin out to 38 hours, OR
- Two text bulletins (01 - 25 hours & 26 - 38 hours)

- 3-space columns (consistent with operational LAMP text bulletins), OR
- 4-space columns (more readable, especially with 100% probabilities)

CP4 100 95 68 87 91 87 85100100 99100 88 77 86 77 75 58 53 46 48 48 48 47 44 41 46 53 58 63 66 66 63 57 52 47 41 35 39 (3-space)

CP4 100 95 68 87 91 87 85 100 100 99 100 88 77 86 77 75 58 53 46 48 48 48 47 44 41 46 53 58 63 66 66 63 57 52 47 41 35 39 (4-space)

- Display Flight Categories with dashes
- Display Flight Categories with 1s

```
VFR --/   +-/   +-------------------------------------------------------------------/
VFR   1     1     1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
```

3 spaces, all projections (cumulative probs)

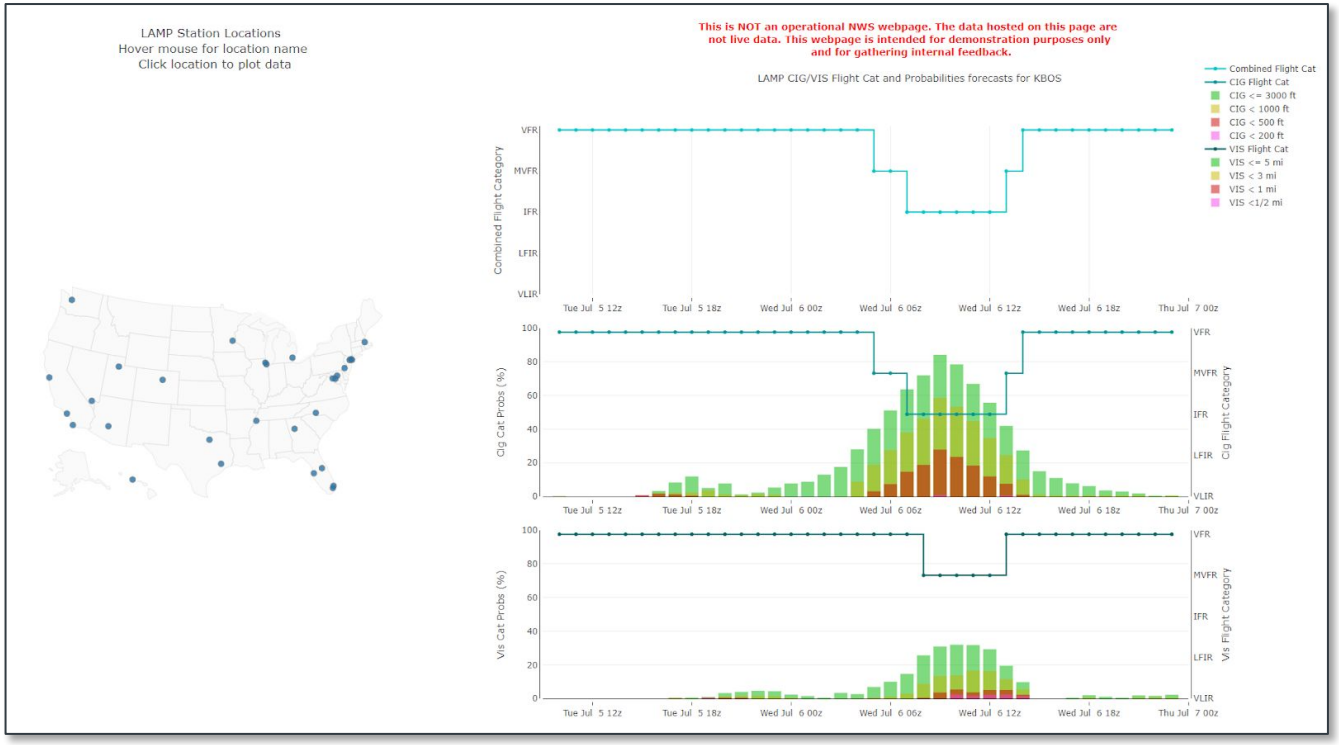
```
KATL   ATLANTA      ASOS     GFS LAMP 1430 UTC   1/05/2022
UTC  15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 00 01 02 03 04
FLT   5  4  5  4  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  4  3  3  3  3  3  4  4  5  5
VFR --/   +-/   +-------------------------------------------------------------------/                       +-----
MVF    +-/   +-/                                                                  +-/                 +----/
IFR                                                                                   +----------------/
LIF
VLI
CIG   8  5  8  5  6  6  6  6  6  8  8  8  8  8  8  8  8  8  8  8  8  8  7  6  6  6  6  5  3  3  3  3  3  4  5  6  7
VIS   7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  6  7  7  7  7  7  7  7  5  5  7  7  7  7  7
CP1   1  1  1  0  0  0  0  0  0  0  0  0  0  0  1  1  1  2  2  3  3  4  4  3  2  1  0  0  0  1  1  1  1  1  1  1  0  1
CP2   3  5  1  0  0  1  0  0  0  2  4  4  4  5  6  7  8  9 10 13 14 16 16 11  5 10  6  4  8 14 17 15 14 14 13  9  5  6
CP3   5 10  1  3  6  5  0  0  1  2  5  6  6  7  9 10 12 11 11 14 17 19 16 11  5 13 15 18 26 35 44 39 35 30 25 17 10 10
CP4  18 43 35 44 37 34 32 33 32 30 16 15 15 14 13 12 13 11 12 14 17 19 18 14  9 16 22 29 43 58 72 67 65 62 50 38 26 21
VP1   0  0  0  1  1  1  0  1  1  0  0  0  0  1  1  2  2  2  3  4  5  6  8  6  2  1  1  1  1  1  2  2  2  2  1  1  1  1
VP2   1  1  1  2  1  1  0  2  1  1  2  1  2  3  3  3  5  5  5  8  9 11 12 11  5  3  3  3  2  3  4  5  5  4  4  3  3  3
VP3   1  1  1  2  2  1  0  2  2  3  4  4  4  5  5  5  6  7  8 11 13 16 18 17  9  9 11 12 12 15 19 19 15 12  9  6  5  5
VP4   1  1  1  2  2  1  0  2  3  5  6  7  6  7  7  8  9 11 12 16 19 24 27 23 15 16 19 20 22 26 31 30 23 19 15 12  9  8
```

Bulletin on onset/cessation times

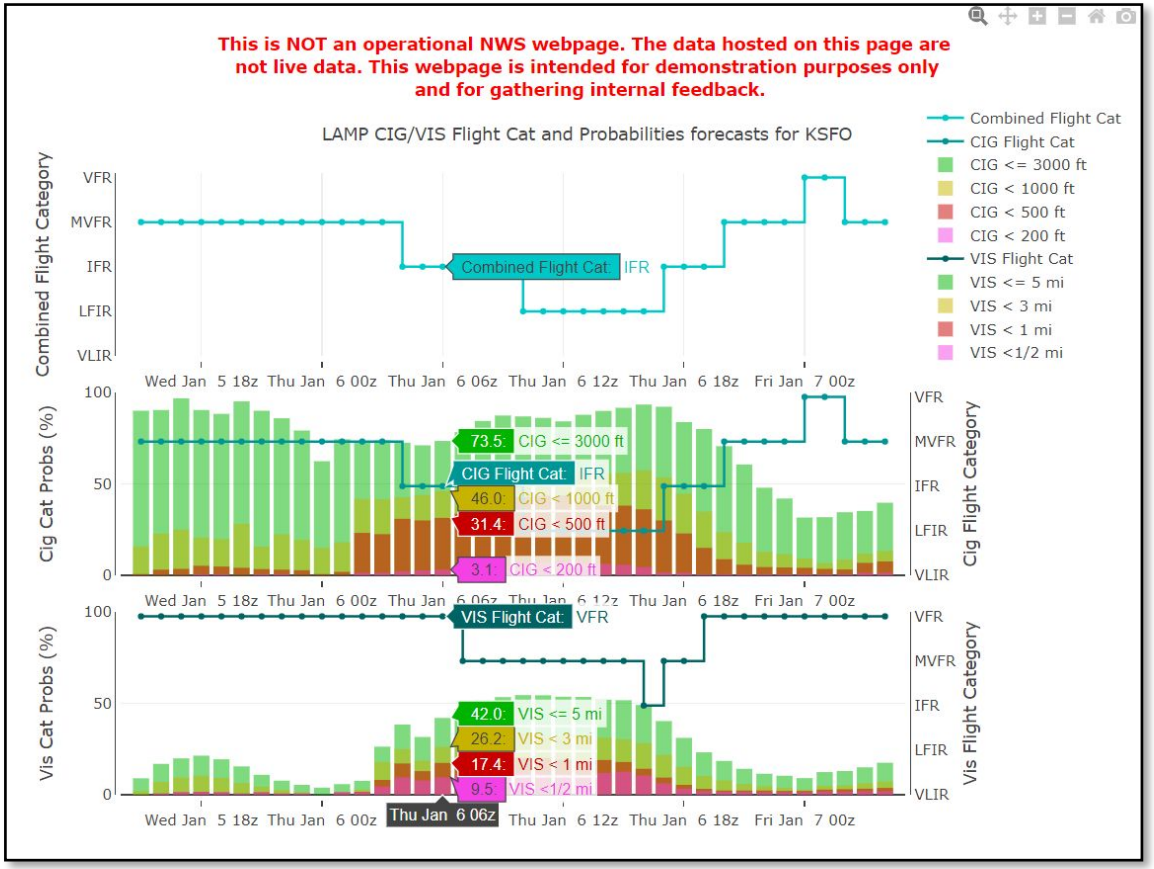
```
KSFO   SAN FRANCISCO          GFS LAMP 1430 UTC   1/05/2022

VFR  07/0000 - 07/0100

MVF  05/1500 - 06/0300   06/2000 - 06/2300   07/0200 -

IFR  06/0400 - 06/0900   06/1700 - 06/1900

LIF  06/1000 - 06/1600
```

Webpage Options - Prototype

Interactive webpage showing Flight Categories and Probabilistic C&V Information

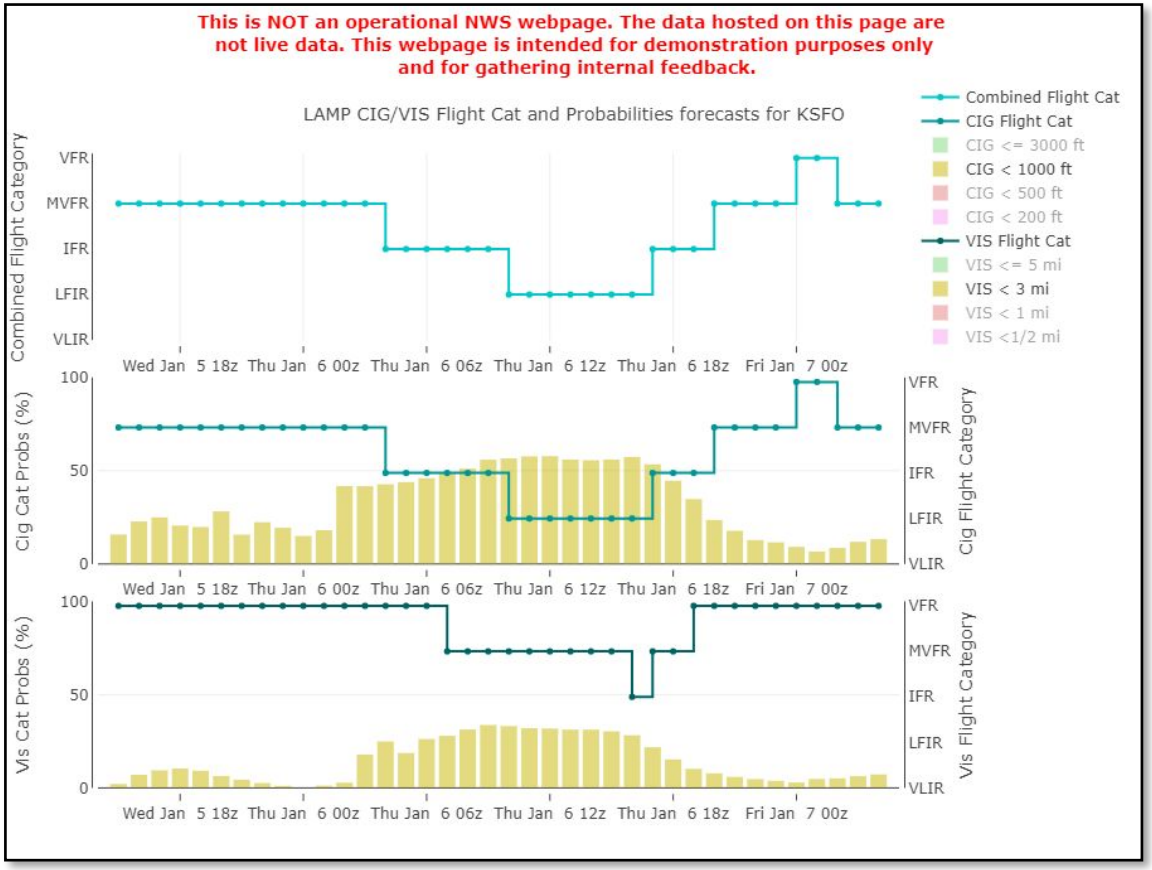


Example Prototype Web Page



Time series plots of combined flight category (top), cumulative ceiling height probabilities (middle), and cumulative visibility probabilities (bottom)

Example Prototype Web Page



Interactive capability to display only probabilities of categories of interest

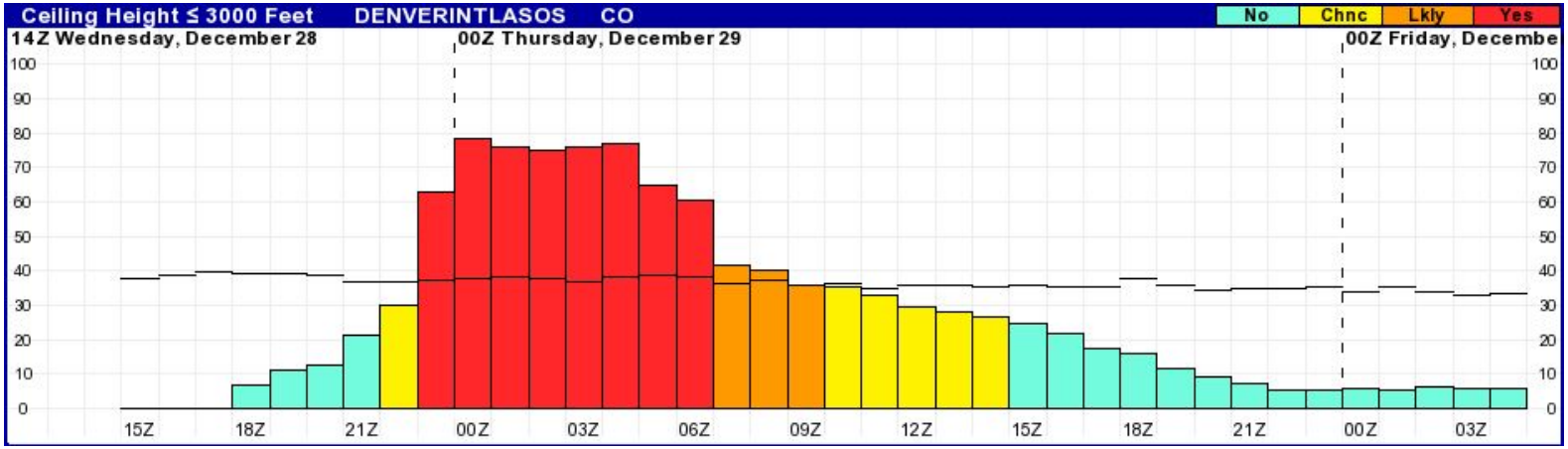
Feedback Received

- Presented the text and web options to small group of FAA and requested feedback
- A common takeaway from the feedback received was the indicated need for airport-specific thresholds for C&V at Core 30 airports and not so much the traditional FCs:
  - "Over-reliance on 'flight categories' concept which are not necessarily aligned with the most important C & V thresholds for NAS users."
- It was also apparent that what meteorologists want may differ from what Traffic Flow Managers want:
  - "I like the initial range of options, particularly with respect to the more simplistic text options. I think this is where it needs to go with air traffic managers. I do think we need to keep in mind the variation in intended audiences (meteorologists vs. air traffic). Having more probabilistic data is very important to meteorologists to CWSU/NAM forecasters and should be readily available to them to interpret the more "deterministic" product given to ATM."

Feedback Received

- Further exemplifying the difference between certain users here were a few differing comments received.
  - “I won't use the text products.”
  - “I like the initial range of options, particularly with respect to the more simplistic text options.”
  - “Not much to dislike! As long as we consider that there are two distinct audiences here.”

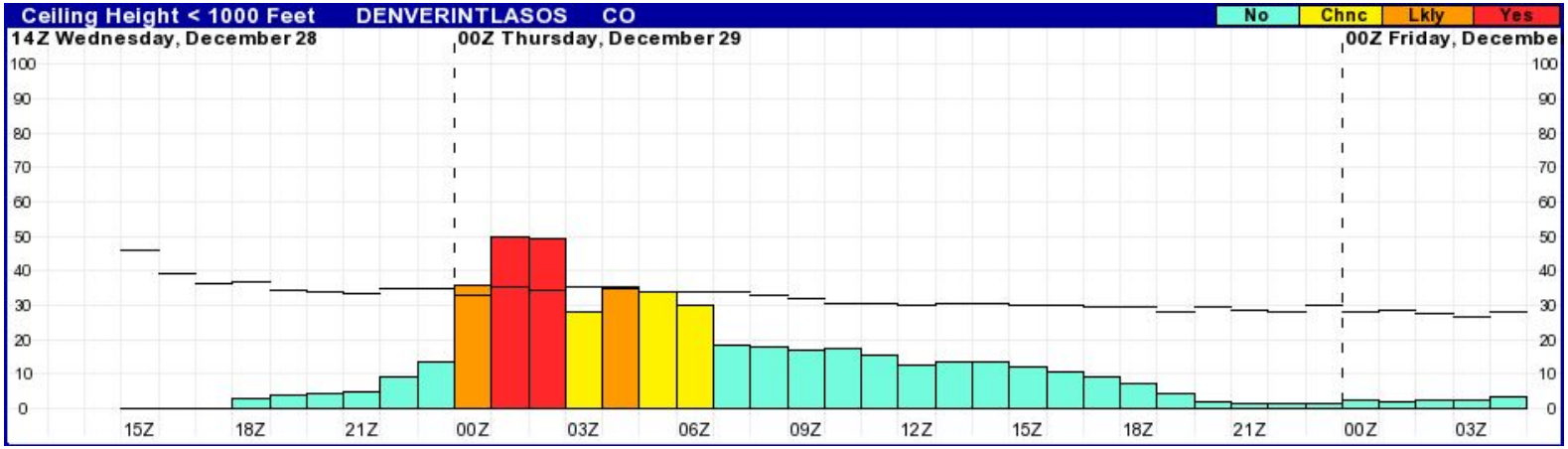
Current Probability Images



LAMP Probability of Ceiling **≤ 3,000** feet at Denver, CO, December 28, 2022, 14z cycle

But this does not indicate the probabilities of ceiling height below 3,000 ft

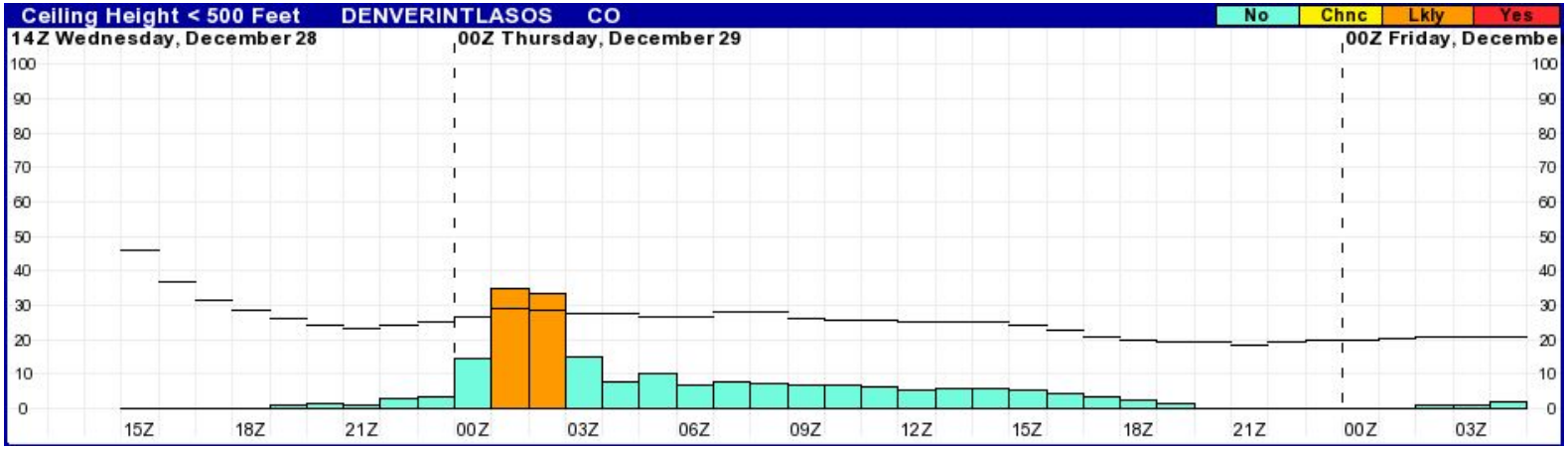
Current Probability Images



LAMP Probability of Ceiling **< 1,000** feet at Denver, CO, December 28, 2022, 14z cycle

But this does not indicate the probabilities of ceiling height below 1,000 ft

Current Probability Images

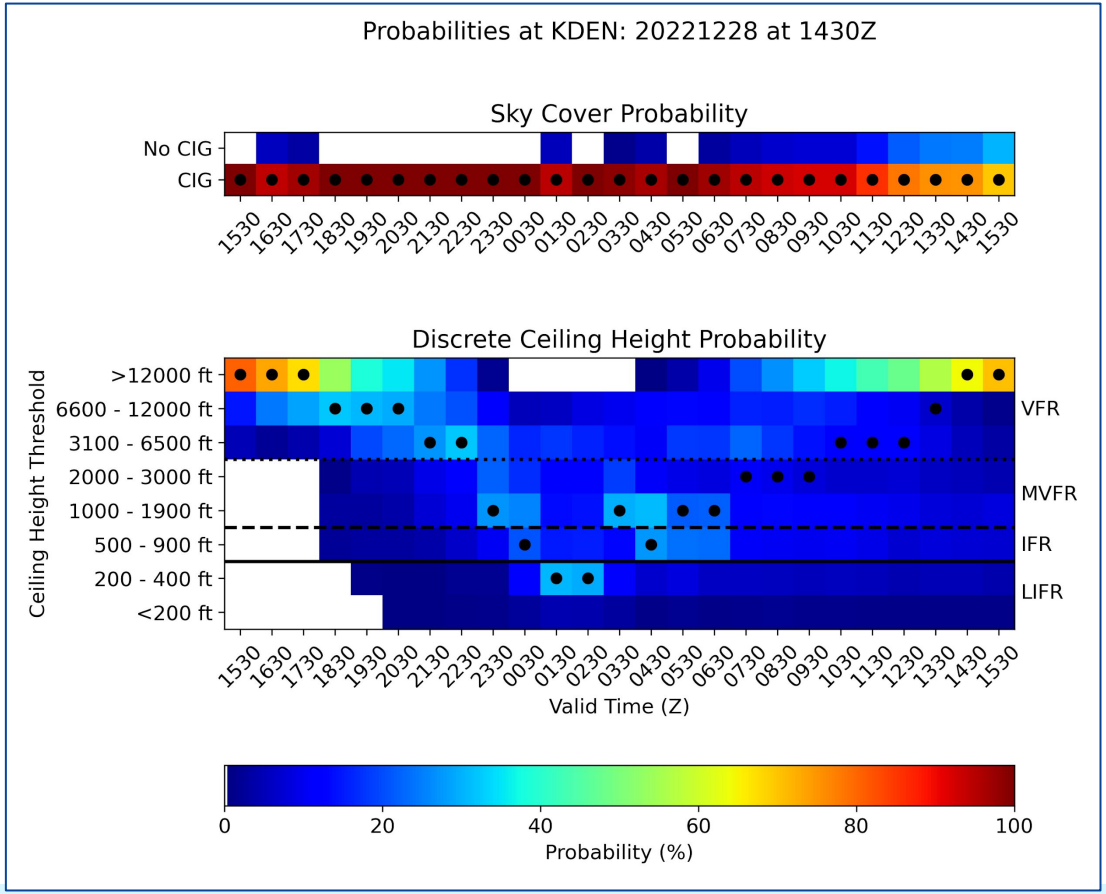


LAMP Probability of Ceiling **< 500** feet at Denver, CO, December 28, 2022, 14z cycle

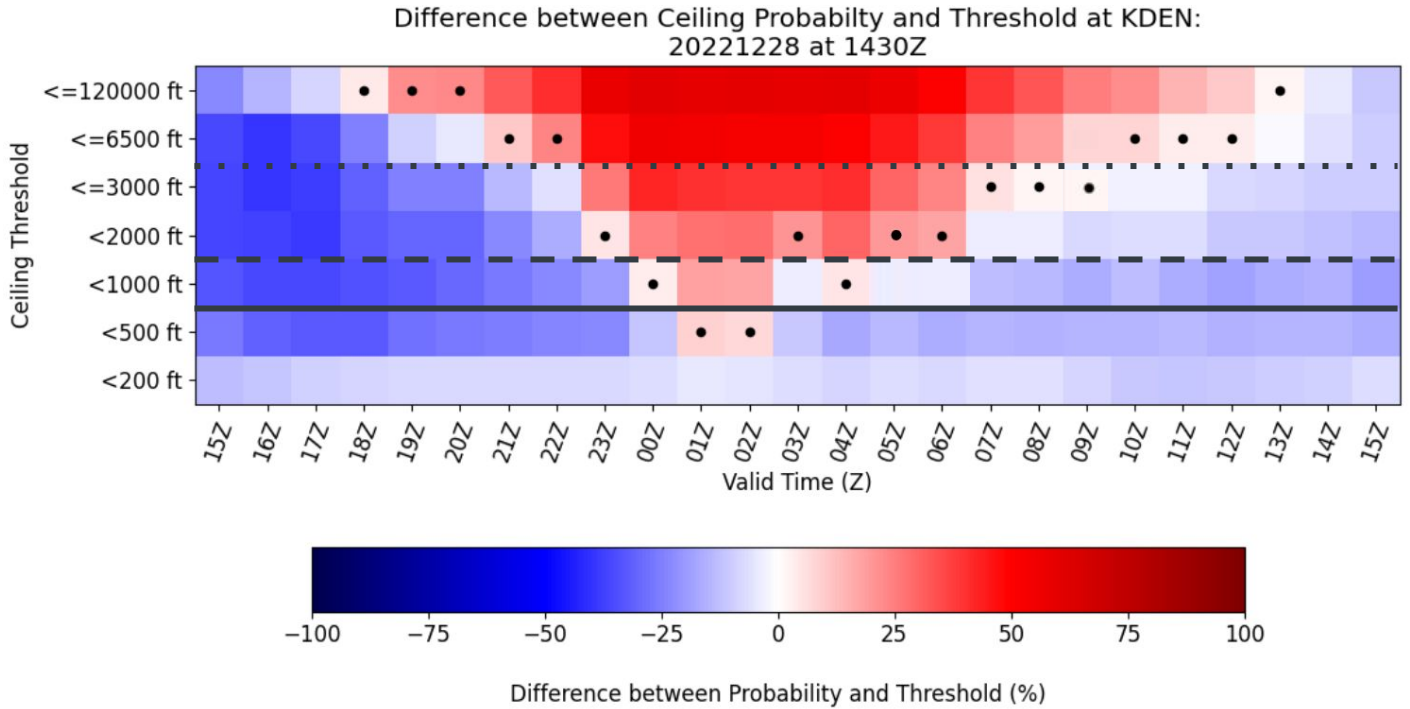
It would aid decision makers to put all of this information together on one display

Additional Graphical Options (Probabilities)

New Images being considered – Probabilities by category



Additional Graphical Options (Prob - Thresholds)



New Images being considered
(Probability – Threshold) differences by category

Summary

- Increased temporal resolution of C&V guidance would benefit IDSS
  - MDL has developed LAMP guidance valid at 15-min timesteps, to be produced every 15 minutes, out to 6 hours
  - Public comment period would be in later 2023; tentative code handoff would be in January 2024 with implementation in Spring 2024
- Calibrated Probabilistic information underlies almost all of the LAMP guidance, but the probabilistic information could be communicated better via new products:
  - Onset/cessation text bulletins and new web graphics showing probabilistic and flight category guidance; different users may want different types of products for IDSS
  - MDL will work with Aviation Weather Center and FAA Aviation Weather Demonstration and Evaluation Team (AWDE) on a user demonstration from late Fall 2023 – early winter 2024.

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Thank you!

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