NATIONAL WEATHER SERVICE

Upcoming Improvements to the LAMP and Gridded LAMP Forecast Guidance for Aviation*

Intermountain West Aviation Weather Safety (IWAWS) Workshop, Reno NV June 10, 2022

Presenter: Phil Shafer, Meteorological Development Laboratory

* Disclaimer: Portions of this research is 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.

Thanks to the LAMP team:

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[3]Ace Info Solutions Inc. (A Guidehouse Company)
[4]KBR, Inc.

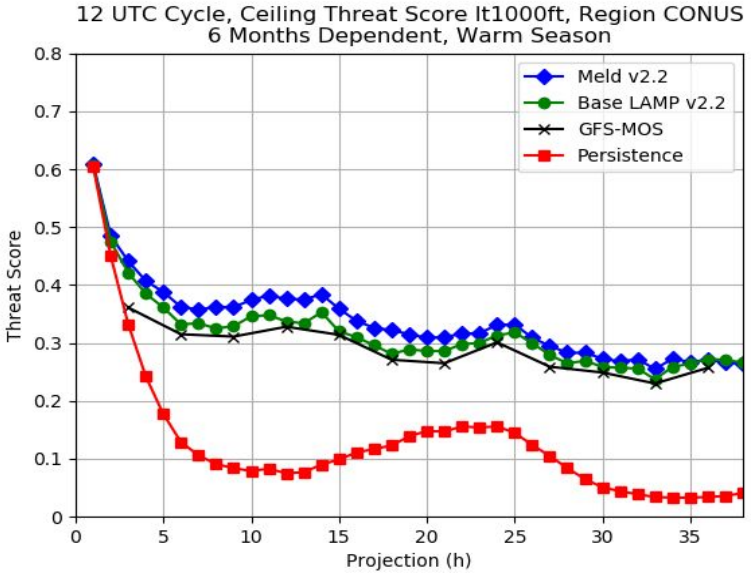
Outline

1. LAMP Background
2. Tour of LAMP/GLMP Web Products
3. Current Work
   - 15-min High Impact Weather C&V Guidance
   - Flight Category Onset/Cessation Guidance
   - Improvements to GLMP Observational Analysis
   - Other upcoming changes (LMP/GLMP v2.5)
4. Future work

1. LAMP Background

LAMP Background

- What is LAMP? LAMP is a statistical system that uses observations, MOS output, and model output to provide guidance for aviation forecasting.
- LAMP acts as an update to MOS guidance.
- LAMP bridges the gap between the observations and the MOS forecast.
- LAMP guidance covers the short-range period of 1-25 hours (38 hours for some elements).
- Runs every hour in NWS operations (every 15 minutes out to 3 hours for ceiling and visibility).
- LAMP supports the National Blend of models (NBM).



Background: LAMP Guidance Details

- LAMP provides station-oriented guidance for:
  - All LAMP forecast elements, ~2010 stations
  - CONUS, Alaska, Hawaii, Puerto Rico
- Gridded LAMP provides gridded guidance for:
  - Lightning & Convection
  - Temperature & Dewpoint
  - Wind Speed & Direction
  - Ceiling Height & Visibility
  - Sky Cover
  - Probability of Precipitation
- Available:
  - At NWS WFOs in AWIPS
  - Via NCEP NOMADS
  - Via website: https://vlab.noaa.gov/mdl/lamp

- Temperature and dewpoint
- Wind speed, direction, and gusts
- Probability of precipitation (on hr)
- Probability of measurable precipitation (1-, 6- and 12-h)
- Precipitation type
- Precipitation characteristics
- Lightning/Convection
- Ceiling height
- Conditional ceiling height
- Opaque sky cover
- Visibility
- Conditional visibility
- Obstruction to vision

Background: LAMP Meld Technique

- Step 1: Base LAMP:
  - Station-based Base LAMP = Observations + locally-run models + GFS MOS
  - Technique = Linear Regression where predictors are statistically related to predictands via regression equations
  - Gridded Base LAMP = Station-based Base LAMP analyzed to a grid

- Step 2: Meld LAMP:
  - Station-based Meld LAMP = Obs + Base LAMP + HRRR MOS
  - Gridded Meld LAMP = Gridded Obs Base LAMP + Gridded forecasts Base LAMP + Gridded HRRR MOS
  - Combining HRRR information with Base LAMP results in increased skill

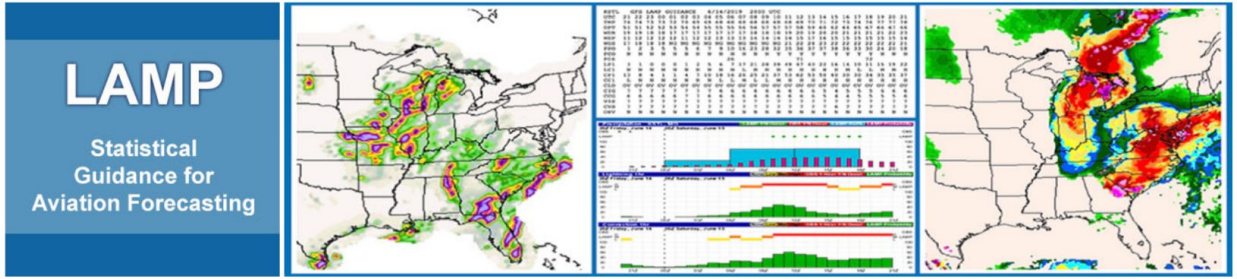
MOS = Model Output Statistics, GFS = Global Forecast System, HRRR = High Resolution Rapid Refresh

2. Tour of LAMP Web Products

LAMP Web Page: https://vlab.noaa.gov/web/mdl/lamp

MDL The Meteorological Development Laboratory

HOME ABOUT MDL PROJECTS PEOPLE PUBLICATIONS



NWS OSTI / MDL / Projects / Localized Aviation MOS Program

As of February 2022, the LAMP pages hosted on the weather.gov server will be transitioning to the NOAA Virtual Lab (home page: https://vlab.noaa.gov/web/mdl/lamp). Please discontinue use of the LAMP weather.gov pages and instead use the LAMP VLab pages. All links to live data still go to the nws.noaa.gov server, so any bookmarks you have to live data should be unaffected by this change, which only impacts the static, informational LAMP webpages.

Please see here for more information about this transition.

Note: While we are transitioning our web pages, all of the products below link to product pages on the old system. Products on those pages are up-to-date, but links on those pages may go to old information or may be broken. Thank you for your patience!

The **Localized Aviation MOS Program** (LAMP) is a statistical system which provides forecast guidance for sensible weather elements. LAMP updates MOS on an hourly basis, is run on NOAA/NWS/NCEP Weather and Climate Operational Supercomputer Systems (WCOSS) computers and disseminated centrally from NCEP, and provides guidance for over 1600 stations as well as gridded observation and forecast guidance on the NDFD CONUS 2.5-km grid out to 25 hours.

LAMP

- LAMP Update and Info +
- Station-based LAMP +
- Gridded LAMP
- Experimental LAMP
- LAMP Data Availability
- LAMP Documentation +
- Archived Products +
- LAMP Verification +
- LAMP Mailing List

LAMP Web Page: https://vlab.noaa.gov/web/mdl/lamp

Please note: LAMP guidance data are operational but webpages and images are not operational and not guaranteed to be available 24x7

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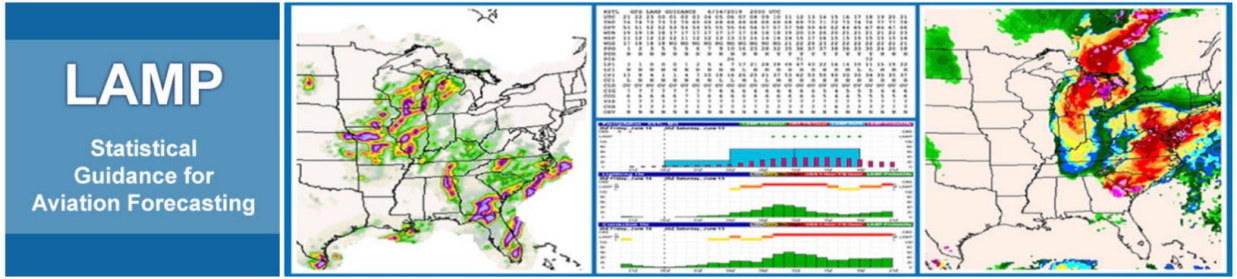

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NWS OSTI / MDL / Projects / Localized Aviation MOS Program / LAMP Update and Info

LAMP Information and Documentation

Information for most recent LAMP/GLMP Upgrade (v2.3) which was implemented on March 22, 2021.

This section deals with the documentation relative to LMP/GLMP v2.3.

- Presentations (download): Slide package for User Evaluation
- Public Information Statement requesting comments
- Experimental LAMP and GLMP graphics and products: GLMP and LAMP experimental web page.
- The **current** LAMP and GLMP WMO headers are unchanged with this implementation. For more details about the WMO headers for these products, please see the links under "WMO Headers" below.
- Presentations: Science Briefing to NCEP (coming soon!).
- Additional Stations: With this implementation making the following station changes:
  - Addition of ceiling height, visibility, 1-h convection, and 1-h lightning guidance for 76 remote stations in Alaska. A separate LAMP text bulletin will be made available on NCEP web services for these 76 remote Alaska stations. Additional elements will be added to these bulletins in the next LMP implementation.
    - List of new 76 remote AK stations with LAMP guidance
- LAMP Alaska Convection and Lightning Verification Report
- Description of the new LAMP v2.3 GFS LAMP Alphanumeric Text Messages
- LAMP Thresholds (v2.3) for AWIPS (effective March 2021)

This guidance is to be used for feedback only and not for flight planning purposes.

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LAMP

- LAMP Update and Info –
- LAMP Prob and Thresh
- LAMP Thresholds +
- LAMP NWS Webservices
- GLMP Background
- LAMP Elements
- LAMP GRIB Encoding +
- LAMP Binary Scaling +
- LAMP Job Sheets
- Station-based LAMP +
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Click here for information on most recent implementation

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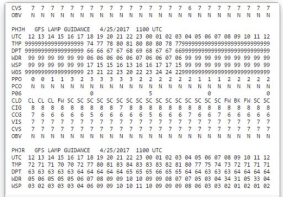
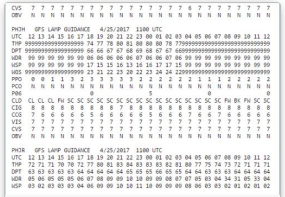
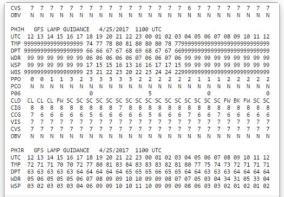


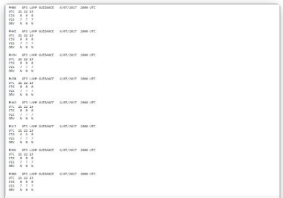
LAMP Full Text Bulletin



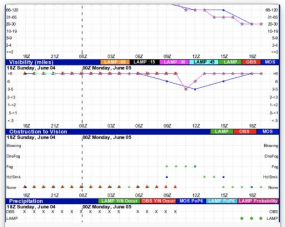
LAMP Text Bulletin by State



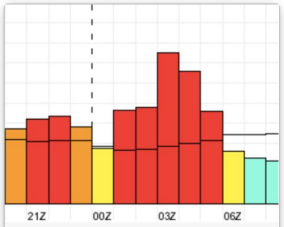
LAMP Text Bulletin by Station



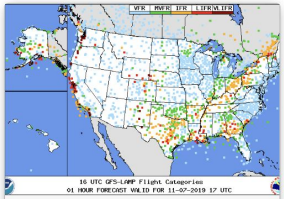
LAMP Bulletin Latest 15 Minute Update



LAMP Forecast Meteograms



LAMP Probability Plots



LAMP Station Forecasts

Click here to find real-time station-based forecast guidance

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LAMP Web Page: https://vlab.noaa.gov/web/mdl/lamp

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KPHX   PHOENIX       ASOS      GFS LAMP GUIDANCE   6/05/2019  2100 UTC
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DPT   37 36 36 35 35 35 36 37 37 38 39 40 41 42 42 42 42 41 40 39 39 38 37 36 36
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WSP   11 12 11 13 13 11 10 08 08 08 05 05 04 04 05 05 06 06 06 06 06 06 07 09 08
WGS   18 19 18 NG NG NG NG NG NG NG NG NG NG NG NG NG NG NG NG NG NG NG NG NG 16
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CCG    8  8  8  8  8  7  7  7  8  7  7  7  8  8  7  7  8  8  8  8  8  8  8  8  8
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CVS    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
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
```

Click here to find LAMP text bulletins

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Click here for meteograms showing future guidance

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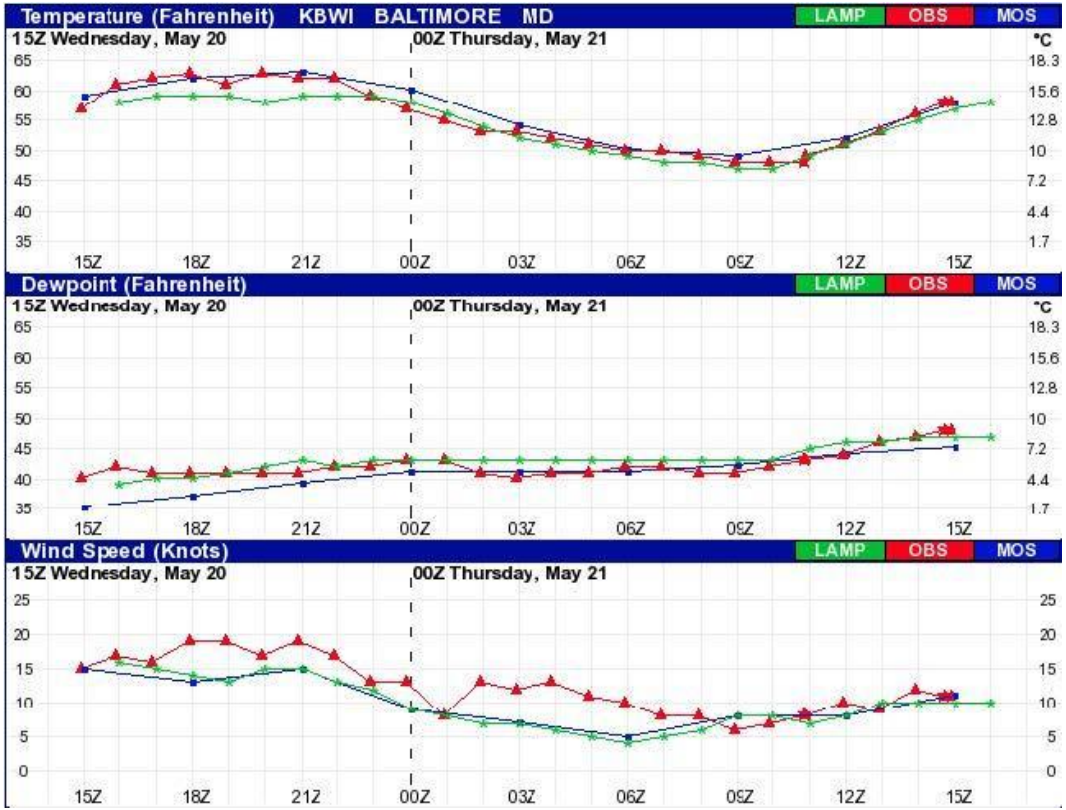

Click here for meteograms showing past guidance and verifying observations

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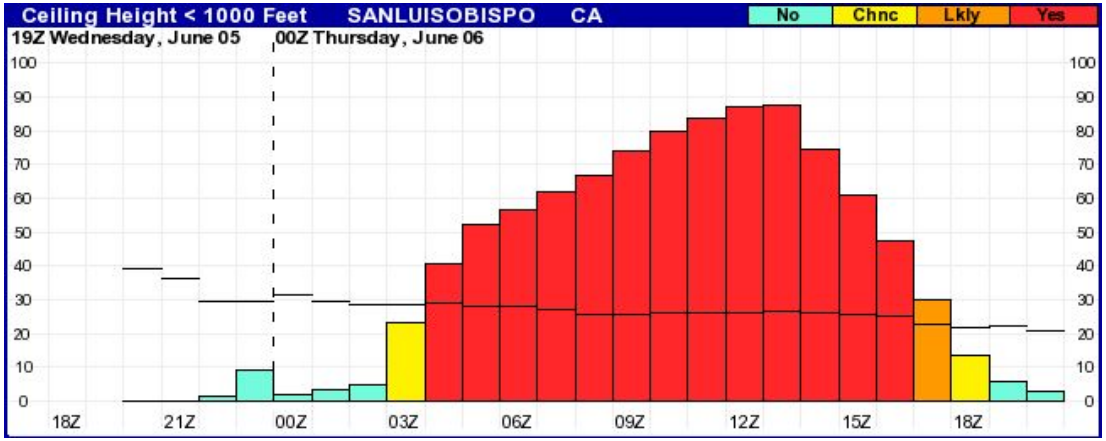

Probabilities (bars) and thresholds (lines) KSBP
Ceiling height < 1,000 feet

Click here for LAMP Probability and Threshold Plots

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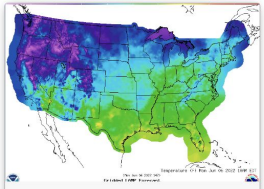
Download Gridded LAMP GRIB2 Data below (Information on Gridded LAMP GRIB2 Data)

This data applies to the CONUS Region and is of the GRIB format.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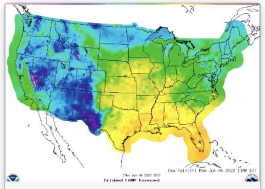
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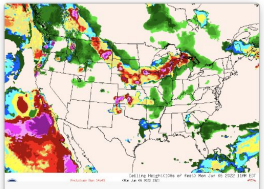
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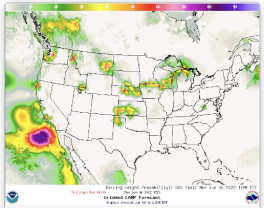
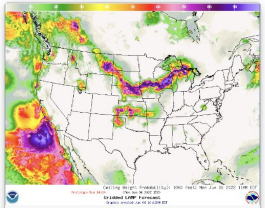

Ceil Prob < 500 ft(%) Images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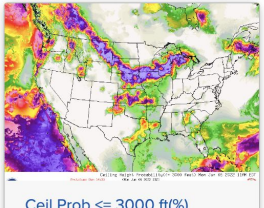
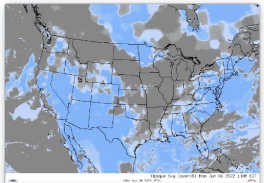
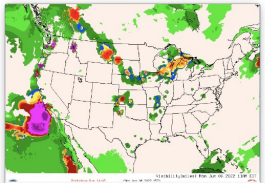

Ceil Prob <= 3000 ft(%) Images


Sky Images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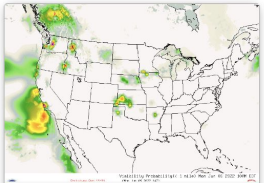
Vis Prob < 1 mi(%)

Click here to find real-time gridded forecast guidance

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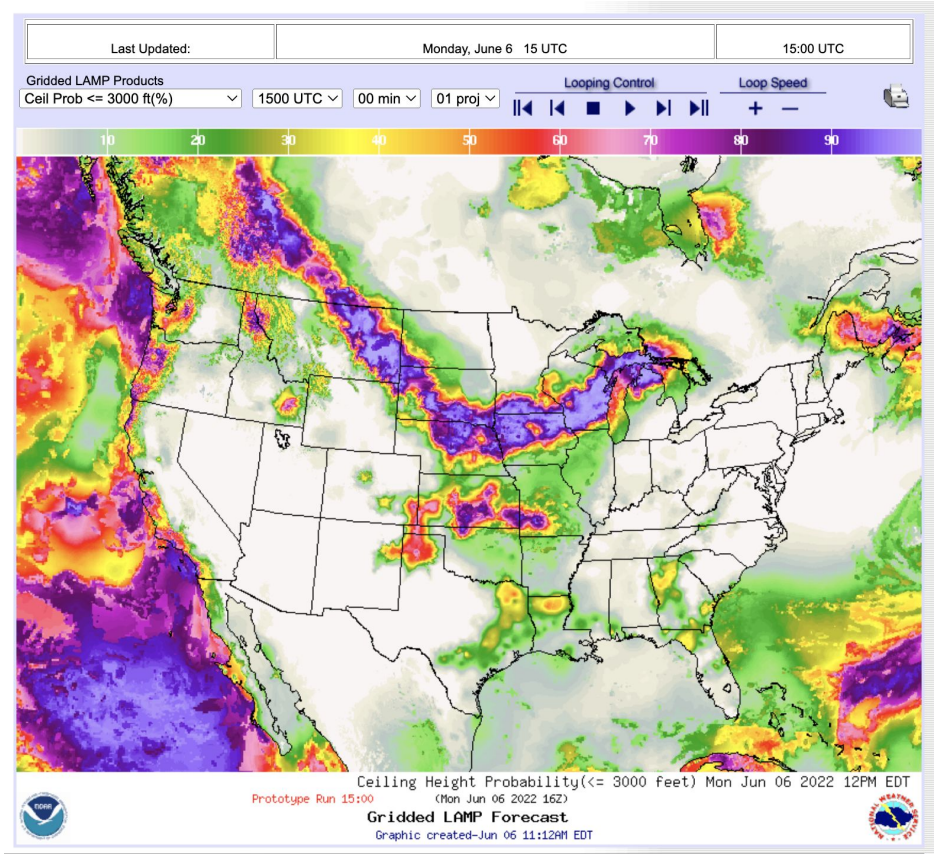

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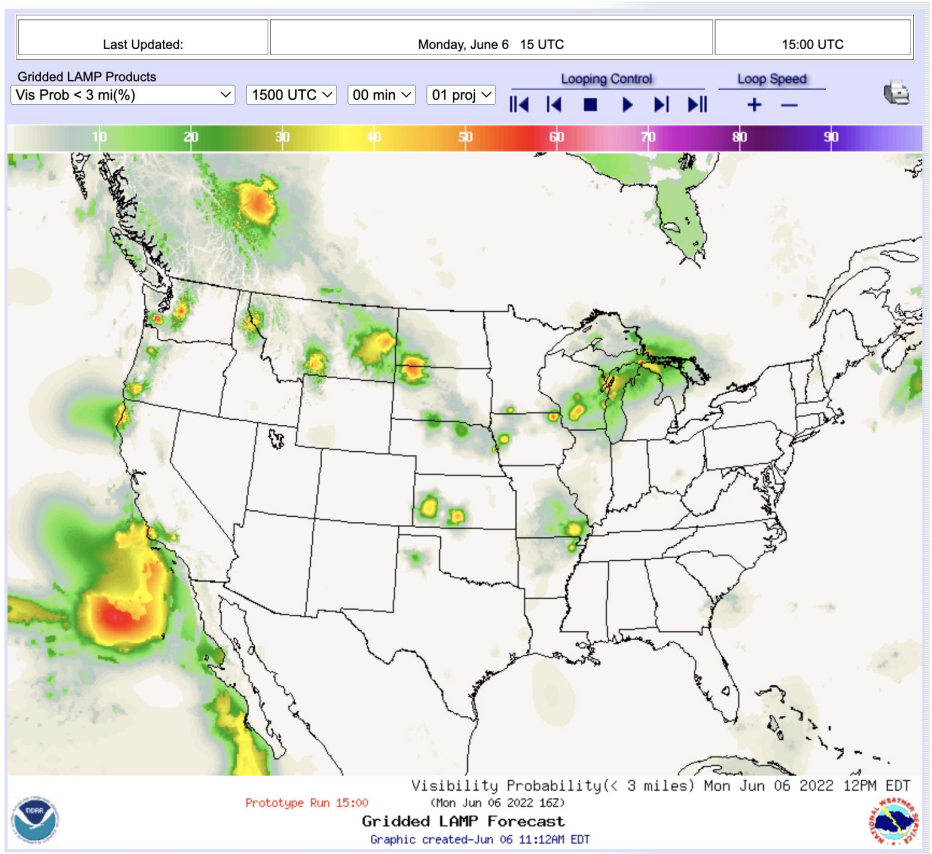

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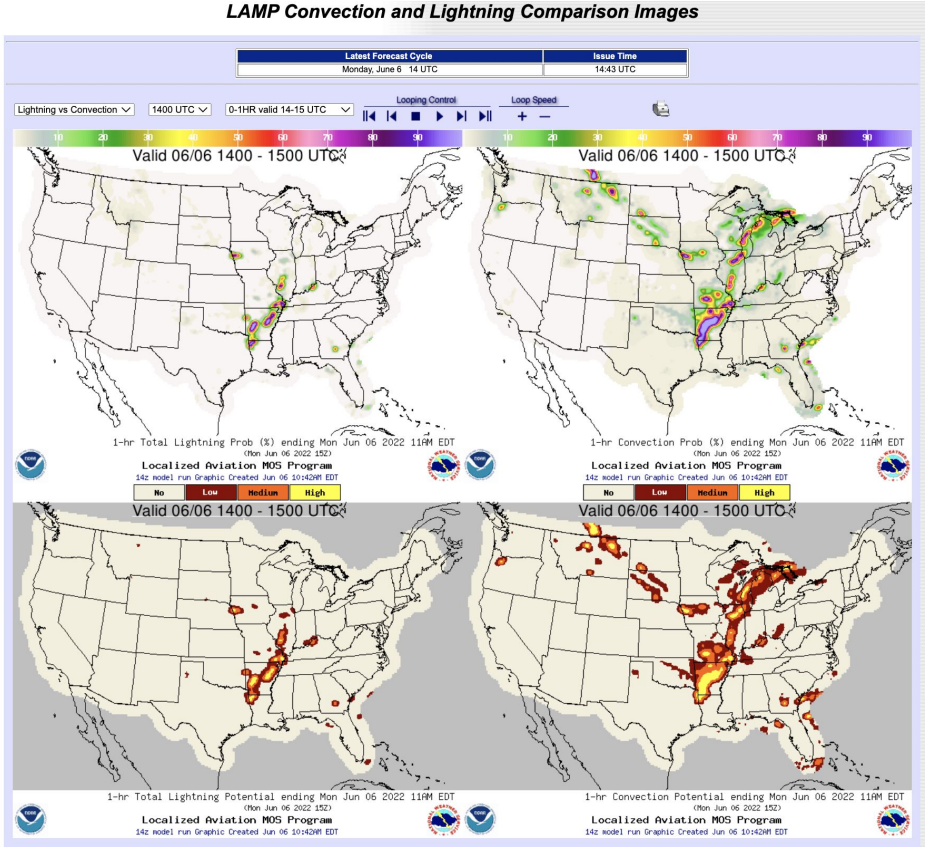

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LAMP/GLMP Experimental Products

LMP/GLMP v2.3 was implemented into operations on March 22, 2021.

New experimental Products will be added when ready.

Click here to find experimental guidance that we are working on implementing

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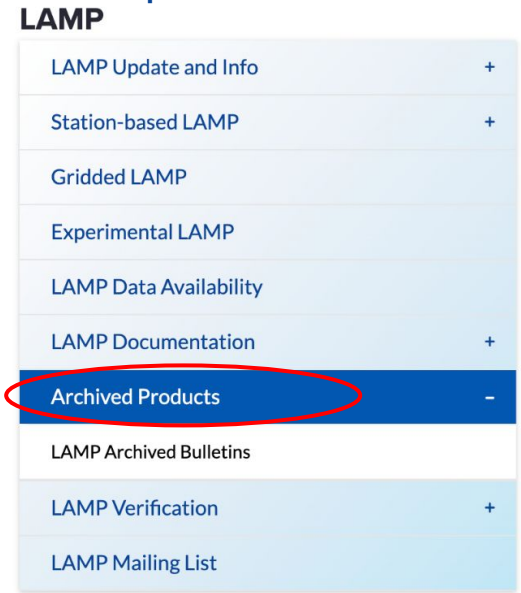
Click here to find archived LAMP products

Active Products

Product	Format	Archive URL
LAV Text Messages	Text	https://vlab.noaa.gov/web/mdl/lamp-archived-bulletins
Convection and Lightning Probability and Potential GRIB2 Files	GRIB	https://lamp.mdl.nws.noaa.gov/glmp/lamp_archive_cnvltg.php



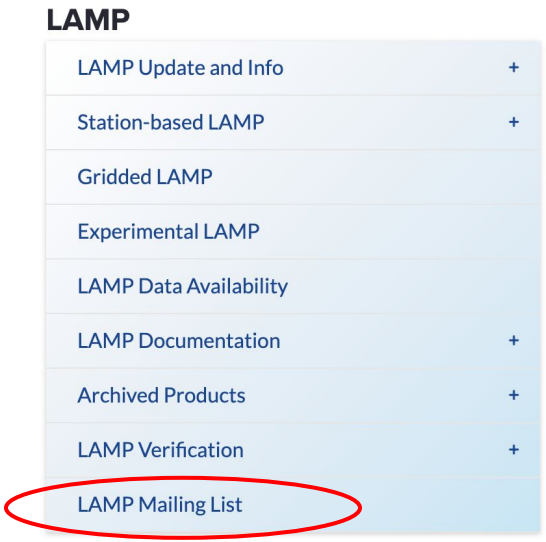
LAMP Web Page: https://vlab.noaa.gov/web/mdl/lamp

Instructions for joining LAMP Mail List

Please email nws.lamp@noaa.gov :

- If you have questions or to report a problem.
- To request to be added to our email list for notifications so that you will be aware of changes to LAMP webpages or other LAMP products.

Click here to join our mailing list



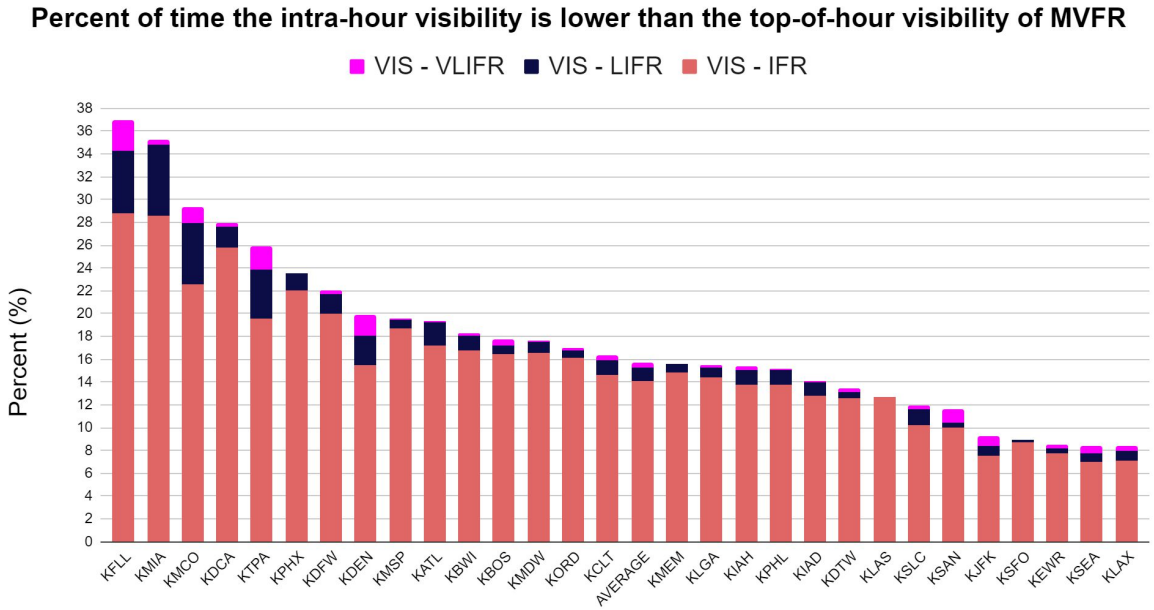
3. Current Work -
15-min High Impact Weather C&V Guidance

Current Work: 15-min HIW C&V Guidance

- FAA-funded project to increase the temporal resolution of Gridded LAMP ceiling height and visibility (C&V) guidance from 1 hour to 15-minutes.
- Helicopter Emergency Medical Services (HEMS) operators use the NWS Aviation Weather Center (AWC) HEMS Tool [planned to be renamed as the Graphical Forecast - Low Altitude (GFA-LA)] which updates every 15 minutes with latest observational data and forecast data.
- Providing updated GLMP guidance for C&V every 15 minutes for 15-minute periods (instead of valid at the top of the hour) will help fill gap in HEMS tool.
- Development of station-based 15-min guidance - complete
- Development of gridded 15-min guidance - in progress

Station-based 15-min HIW C&V Guidance

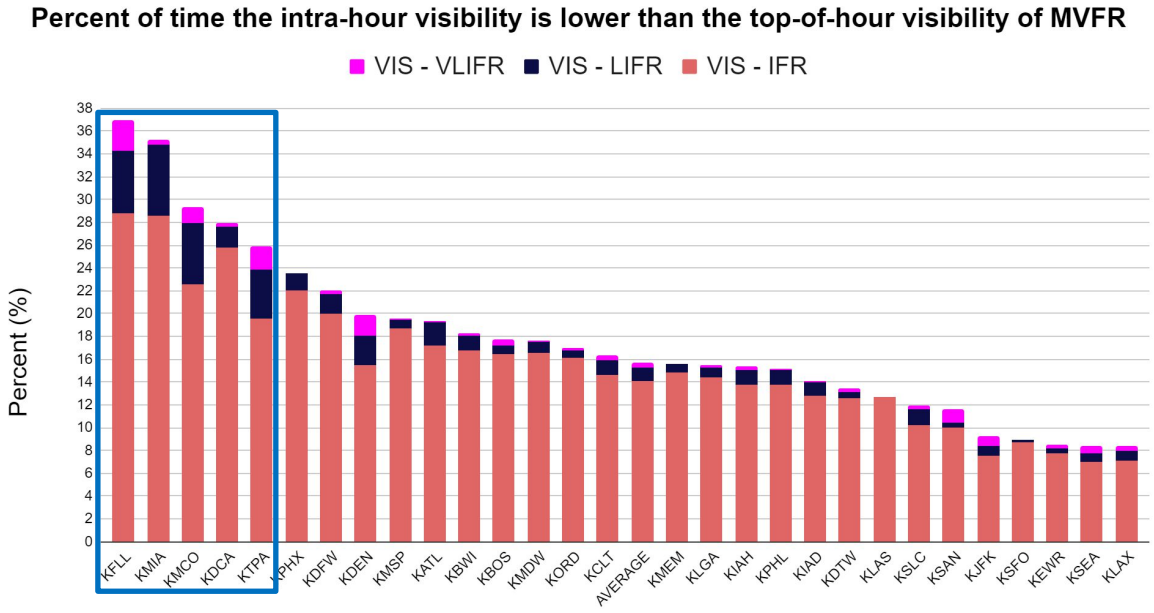
- Predictand defined as lowest ceiling height or lowest visibility observed over a 15-minute period ending at HH:14, HH:29, HH:44, and HH:59.
- How often do top of hour (TOH) observations miss impactful events that occur during the hour?
- Intra-hour variability higher for visibility than for ceiling.



Station-based 15-min HIW C&V Guidance

- Predictand defined as lowest ceiling height or lowest visibility observed over a 15-minute period ending at HH:14, HH:29, HH:44, and HH:59.
- How often do top of hour (TOH) observations miss impactful events that occur during the hour?
- Intra-hour variability higher for visibility than for ceiling.

  Four of top 5 in Florida!

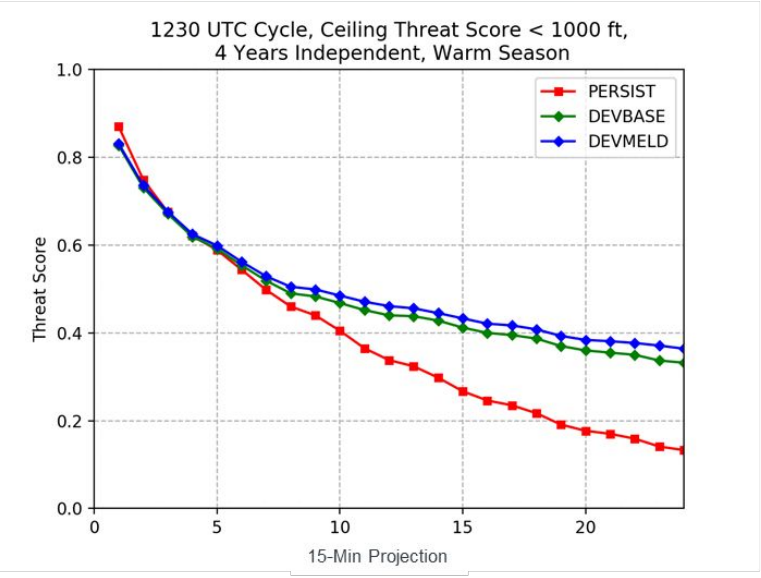


Station-based 15-min HIW C&V Guidance

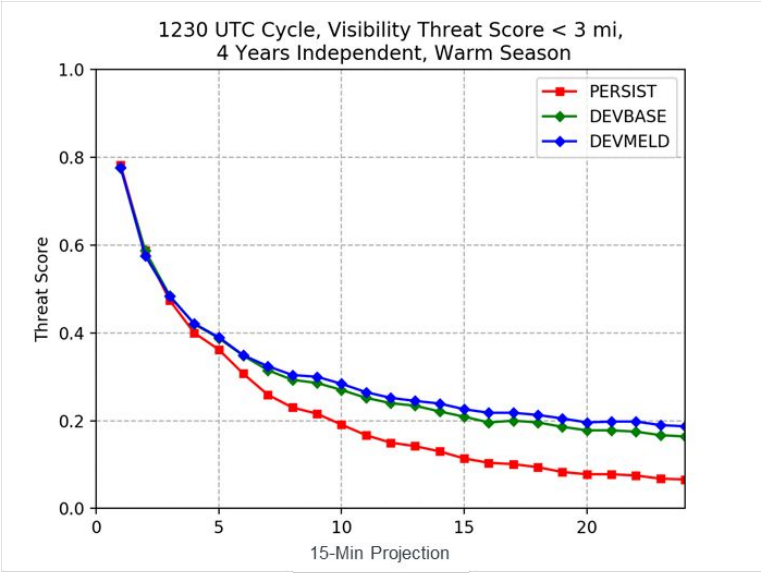
- 15-min “Base LAMP”, “HRRR MOS”, and “Meld LAMP” equations were developed out to 6 hours:
  - 15-min C&V predictand
  - Development sample (2017-2020)
  - Warm (Apr-Sept) and Cool (Oct-Mar) seasons
  - “Base LAMP” was regionalized, “HRRR MOS” and “Meld” were developed using one region for entire CONUS
- Meld = 15-min “Base LAMP” + 15-min “HRRR MOS”
- K-fold cross-validation - each season held out as independent, repeated for each season. All independent seasons verified against 15-min predictand.

15-min Meld LAMP Verification: Warm Season

Ceiling < 1,000 feet



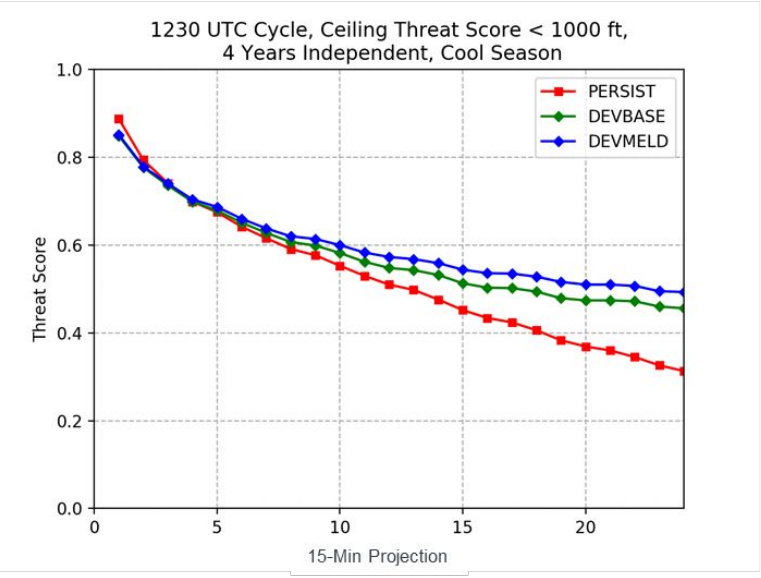
Visibility < 3 miles



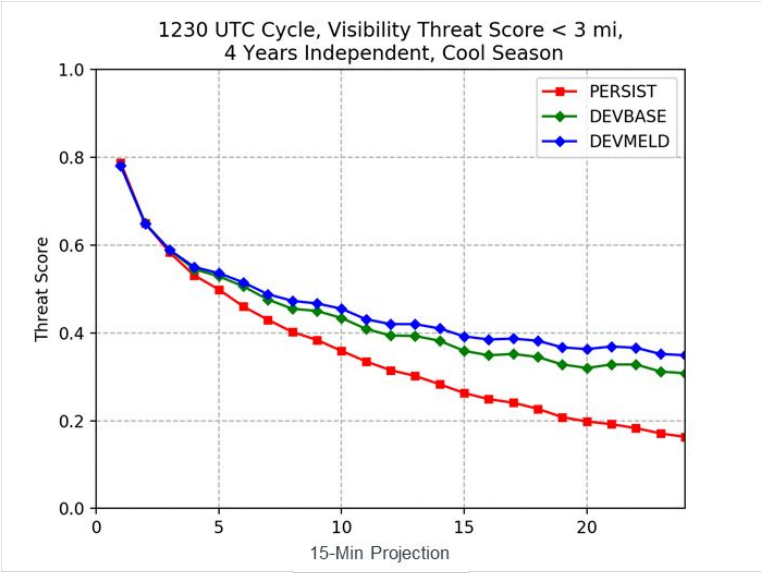
15-min Meld LAMP (blue) shows improvement over 15-min Base LAMP (green) at later projections due to the decreased predictive strength of the observation and the increasing predictive strength of the HRRR

15-min Meld LAMP Verification: Cool Season

Ceiling < 1,000 feet



Visibility < 3 miles



15-min Meld LAMP (blue) shows improvement over 15-min Base LAMP (green) at later projections due to the decreased predictive strength of the observation and the increasing predictive strength of the HRRR

Current Work: 15-min C&V Gridded Guidance

- Work is underway to develop 15-min Gridded LAMP guidance for HIW C&V out to 6 hours.
- Station-based 15-min guidance developed previously is being updated:
  - To include more recent data
  - Clustering techniques are being explored for defining new regions for the station-based guidance.
- Gridded LAMP software will be modified to analyze 15-min station-based guidance to the 2.5-km GLMP CONUS grid.

3. Current Work -
Flight Category Onset/Cessation Guidance at Core 30 Airports

Current Work: Flight Category Onset/Cessation

- FAA-funded work to produce prototype guidance indicating the time of onset and cessation of flight categories (FCs) at Core 30 airports.
- LAMP currently provides probabilistic and deterministic guidance for C&V but not for FCs directly (requires knowing the probability of a FC based on ceiling and visibility, which LAMP currently does not provide).
- LAMP information could be repackaged into a product that provides forecast guidance indicating the forecasted time (at hourly resolution) for onset and cessation of various FCs at Core 30 airports.
- Prototype text bulletins and web graphics options were developed from hourly station-based LAMP guidance and presented to FAA stakeholders for feedback.

Example Prototype Text Bulletin

```
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  5  4  3  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  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  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
```

One bulletin for 1-38 hours

Flight category indicated with numeric value (1:VLIFR, 2:LIFR, 3:IFR, 4:MVFR, 5:VFR)

Example Prototype Text Bulletin

```
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  5  4  3  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  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  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
```

FC onset indicated by “+”, cessation indicated by “/”, and prevailing condition indicated with dashes “--”

Example Prototype Text Bulletin

```
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  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  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  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
```

Traditional LAMP C&V categories (not the same as FCs)

Example Prototype Text Bulletin

```
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  5  4  3  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  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  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
```

Cumulative probabilities for each FC (up to MVFR)

Example Prototype Text Bulletin

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	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	V	V	M	I	I	I	I	I	I	M	M	V	V
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	1										1	1
MVF		1		1																								1							1	1		
IFR																													1	1	1	1	1	1				
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	7
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
CPVFR	82	57	65	56	63	66	68	67	68	70	84	85	85	86	87	88	87	89	88	86	83	81	82	86	91	84	78	71	57	42	28	33	35	38	50	62	74	79
VPVL	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	2	2	2	4	5	5	8	5	1	1	1	1	1	1	1	2	1	1	1	0	0	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
VPVFR	99	99	99	98	98	99	100	98	97	95	94	93	94	93	93	92	91	89	88	84	81	76	73	77	85	84	81	80	78	74	69	70	77	81	85	88	91	92

Additional format options:

- FC indicated by letters V/M/I/L
- Onset/cessation indicated by “1”

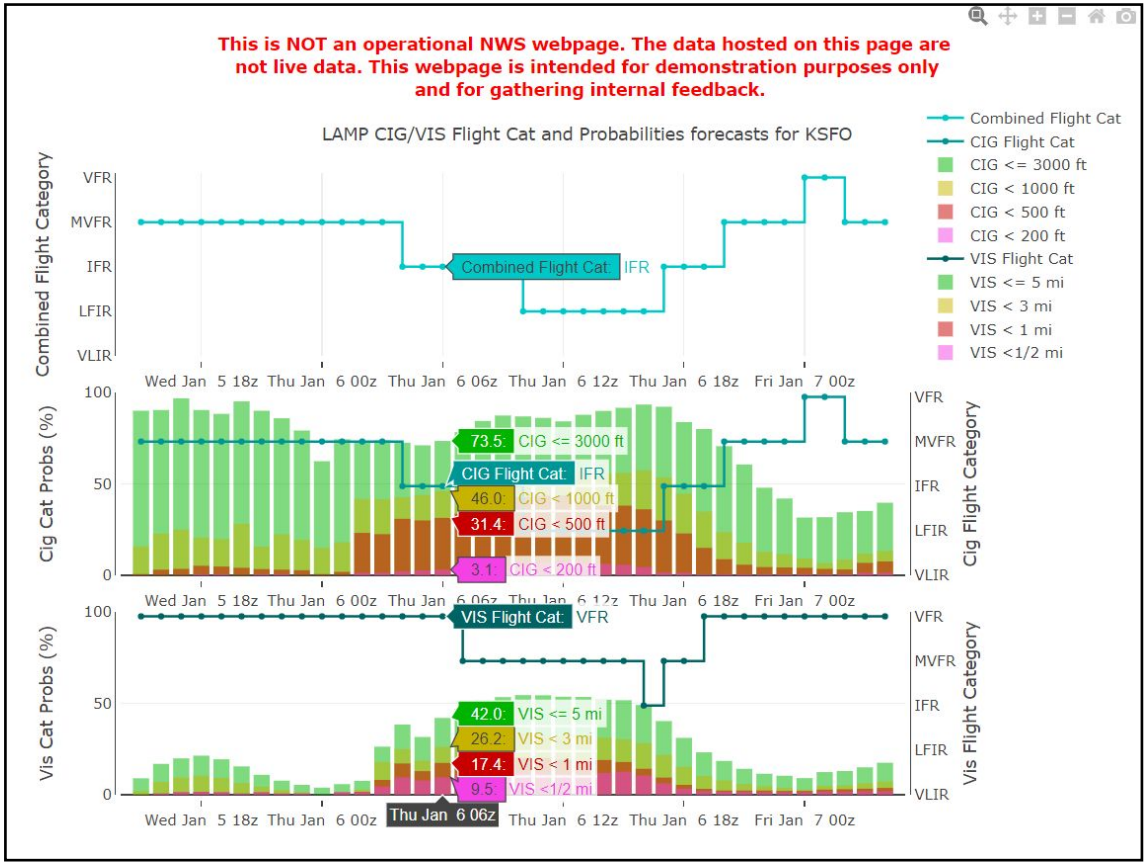
Example Prototype Text Bulletin

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	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	V	V	M	I	I	I	I	I	I	M	M	V	V
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	1										1	1
MVF		1		1																								1							1	1		
IFR																													1	1	1	1	1	1				
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	7
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
CPVFR	82	57	65	56	63	66	68	67	68	70	84	85	85	86	87	88	87	89	88	86	83	81	82	86	91	84	78	71	57	42	28	33	35	38	50	62	74	79
VPVL	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	2	2	2	4	5	5	8	5	1	1	1	1	1	1	1	2	1	1	1	0	0	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
VPVFR	99	99	99	98	98	99	100	98	97	95	94	93	94	93	93	92	91	89	88	84	81	76	73	77	85	84	81	80	78	74	69	70	77	81	85	88	91	92

Additional format options:

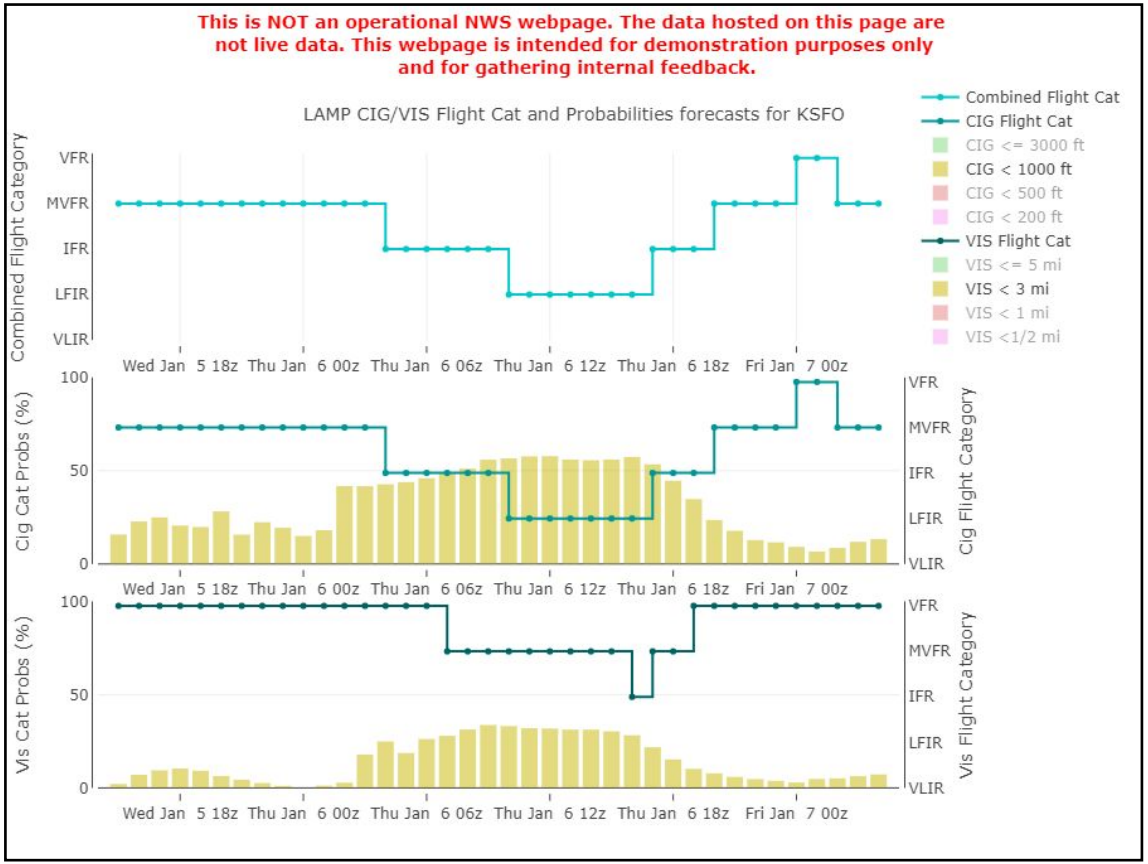
- Probability of clearing due to ceiling height (CPVFR)
- Probability of clearing due to visibility (VPVFR)

Example Prototype Web Page



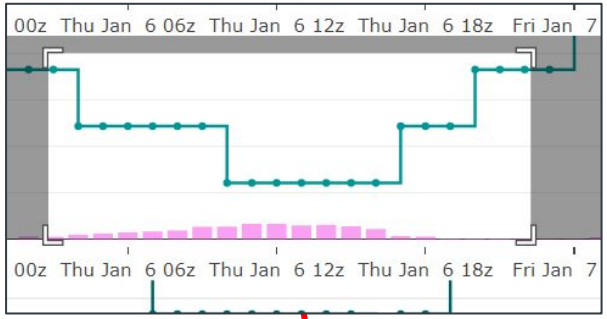
Time series plots of combined flight category (top), cumulative ceiling height probabilities (middle), and cumulative visibility probabilities (bottom)

Example Prototype Web Page

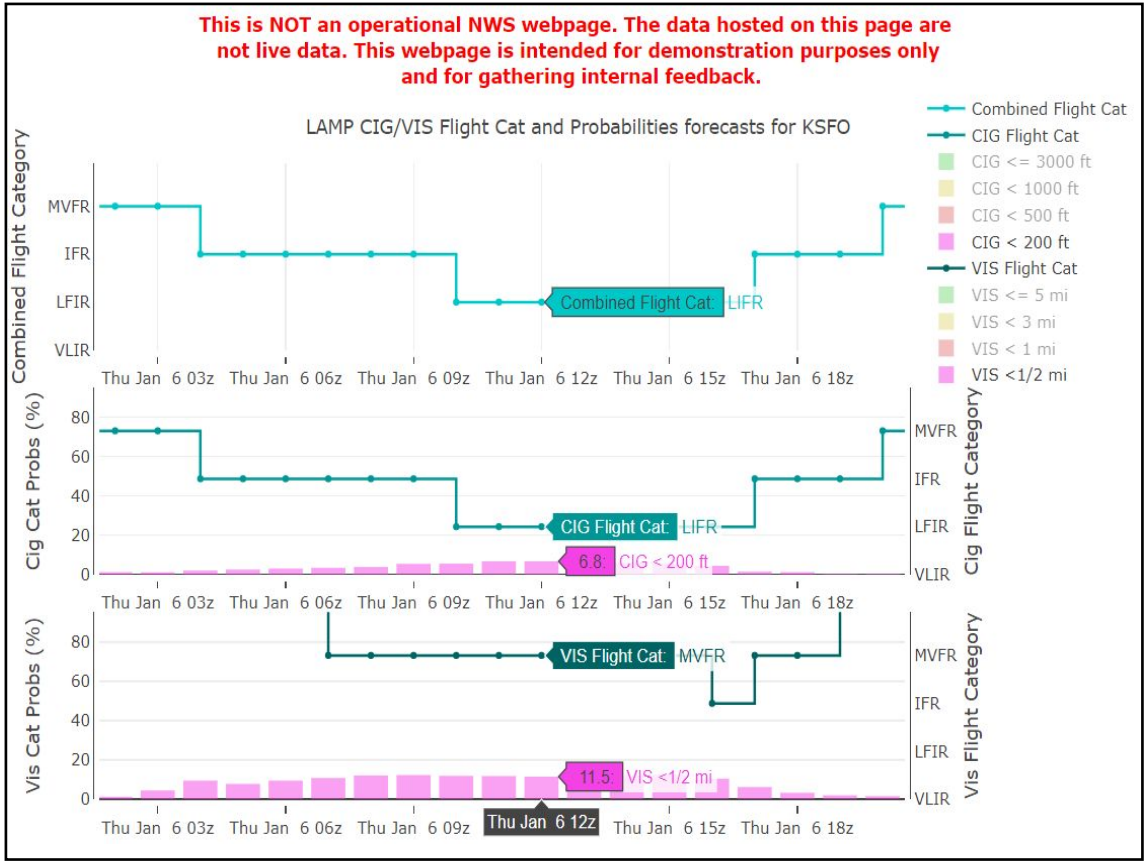


Interactive capability to display only probabilities of categories of interest

Example Prototype Web Page



Capability to zoom to specific time range and hover over image to display values



Summary of User 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.”
- “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.”

Summary of User Feedback

- Diversity of user opinions:
  - “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.”
- MDL is currently working with the FAA to finalize the product format options based on user feedback received.
- Planned follow-on work: MDL has been tasked by FAA to produce similar prototypes for onset/cessation of FCs at 15-min time steps out to 6 hours, using 15-min C&V guidance previously developed.

3. Current Work -
Improvements to GLMP Observational Analysis for C&V

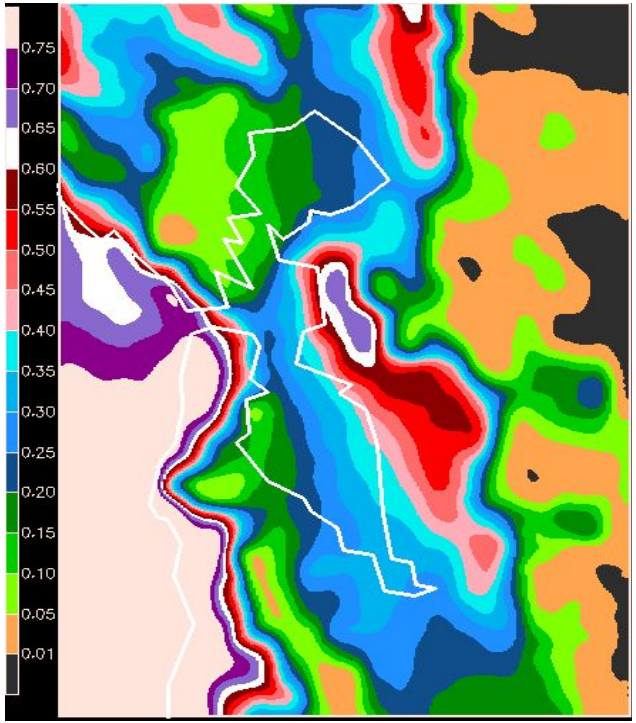
Improvements to GLMP Observational Analysis

- GLMP analyses fit the observations very well, but may have degraded performance between the observing stations.
- There is a critical need to improve the gridded observational analyses in between the traditional observing stations. For example, ceiling heights below 1700 ft on the approach to the San Francisco Airport (SFO) may impact arrival rates.
- MDL was tasked by FAA to investigate techniques to improve the GLMP analysis between stations, including developing regression equations to produce pseudo-observations on a grid around the SFO area.

Improvements to GLMP Observational Analysis

- Primary task milestones:
  - Develop equations for pseudo-observations (pseudo-obs) of ceiling height at grid points over the SFO area.
  - Investigate the utility of satellite data as a predictor in the pseudo-obs equations. Satellite data offers a science opportunity to provide additional information about the ceiling heights in between the traditional observation locations.
  - Investigate Artificial Intelligence / Machine Learning (AI/ML) techniques in the development of the pseudo-obs.

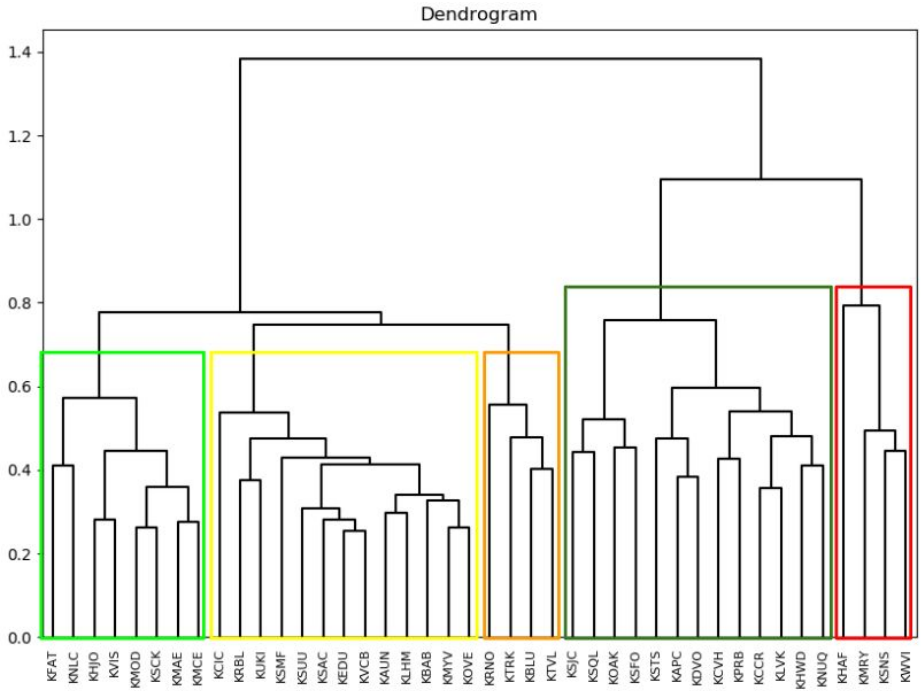
HRRR-Based Proxy Climatology over SFO



HRRR CIG RF < 1700 ft, July, 1200 UTC

- HRRR-based ceiling height relative frequencies (RFs) were calculated for all grid points over SFO domain for each month, time of day, and several ceiling thresholds.
- Serves as proxy climatology predictor in pseudo-obs equations.
- RFs for < 1700 ft threshold depict low ceilings just offshore and areas east of the Bay.

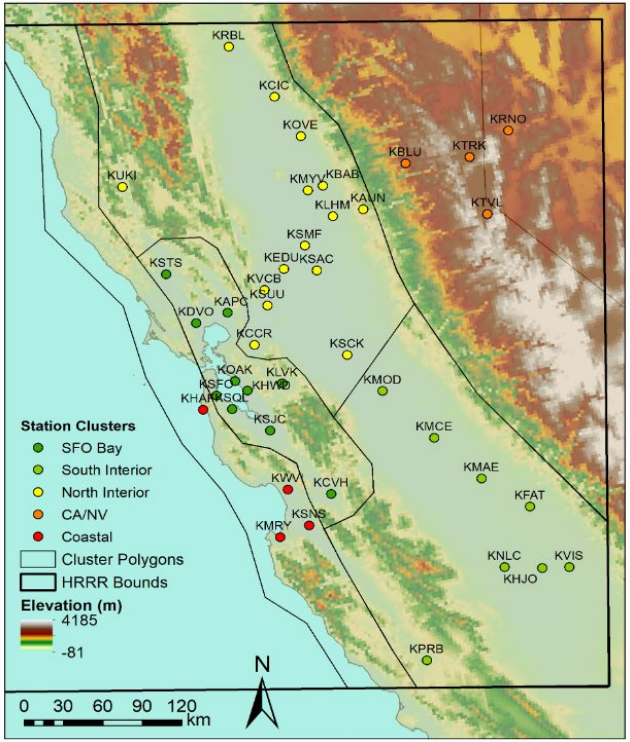
Cluster Analysis of Stations over SFO



Dendrogram showing relationships between 42 SFO area stations based on hierarchical clustering

- Cluster analysis was applied to ceiling height observations from 42 METAR stations in the SFO region.
- Hierarchical clustering finds natural splits in the data.
- Naturally-occurring clusters reinforce the idea that there are similarities in the observed ceiling heights at stations closer together.

Cluster Analysis of Stations over SFO



Map of stations classified by cluster and cluster polygons

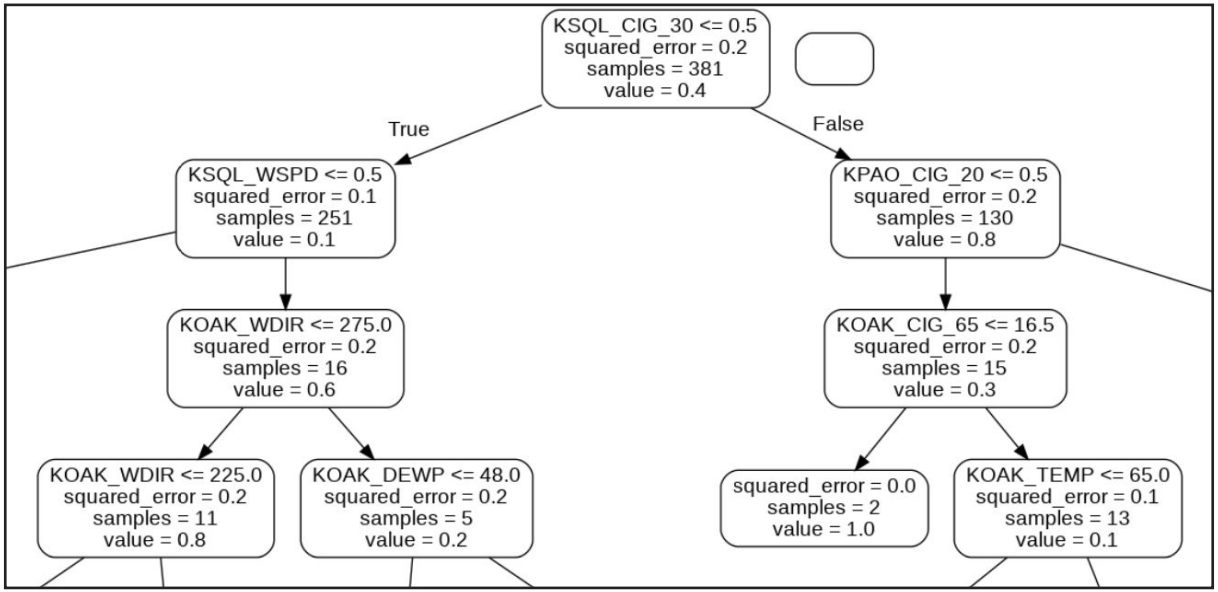
- Polygons were created in GIS to define the boundaries between each cluster.
- Clusters can be used for testing regionalization of predictors and pseudo-ob equations.
- We will continue to explore these techniques for other applications in LAMP.

Random Forest “Smart” Predictor

- A Random Forest model was used to create a “smart” predictor based on nearby observations, that indicates whether or not a ceiling (defined by ≤ 12,000 ft) is likely to be observed at a given station, for input to the LAMP pseudo-ob equation development.
  - Separate models for summer stratus season (15 May - 15 Oct) and all dates outside stratus season.
  - Separate models for each of the five clusters.

- “Features” considered for inclusion in the model: Nearby observations of temperature, dewpoint, wind, ceiling height, visibility, sky cover, day of the year, hour of the day, and variance of ceiling height.

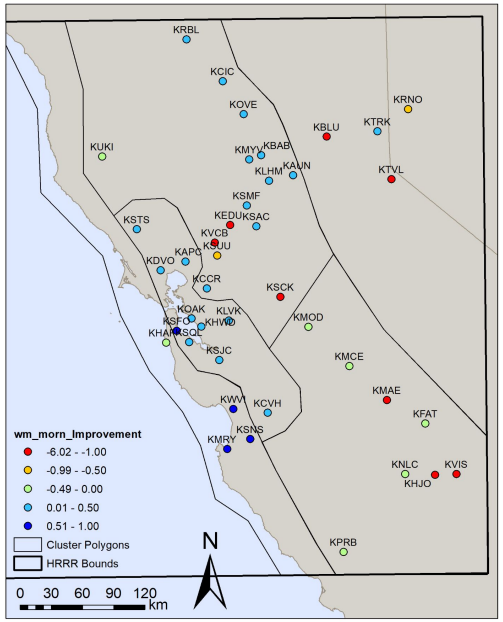
Example Decision Tree from Random Forest



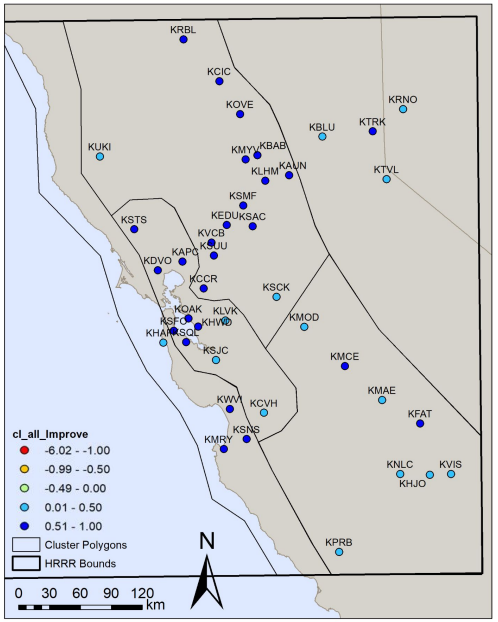
- Most important feature for KSFO is Ceiling < 3000 ft at nearby station KSQL
- Wind speed and direction at KSQL and KOAK also contribute

Random Forest “Smart” Predictor Verification

- Greatest skill during stratus season for stations along the coast and around the Bay, lowest skill for stations inland.
- Model does not perform as well where there are few ceiling events.
- Non-stratus season results are skillful everywhere (ceilings tend to be more homogeneous during this period).



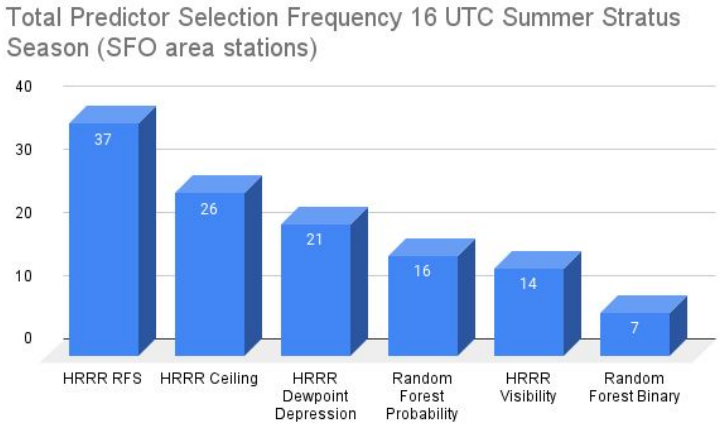
Percent improvement (+ values) or degradation (- values) in Brier Score, Stratus Season

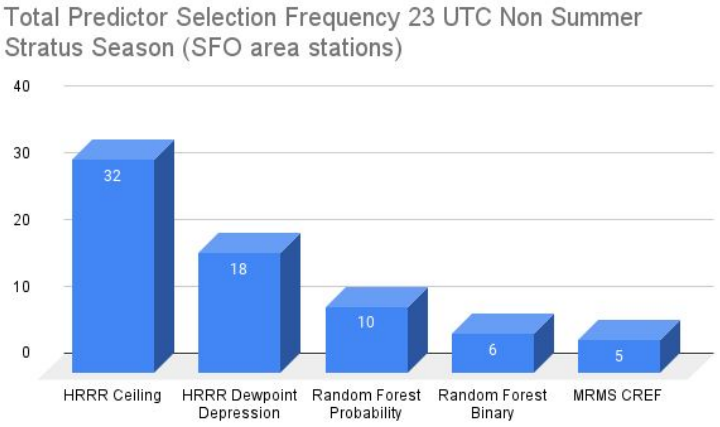


Percent improvement (+ values) or degradation (- values) in Brier Score, Non-Stratus Season

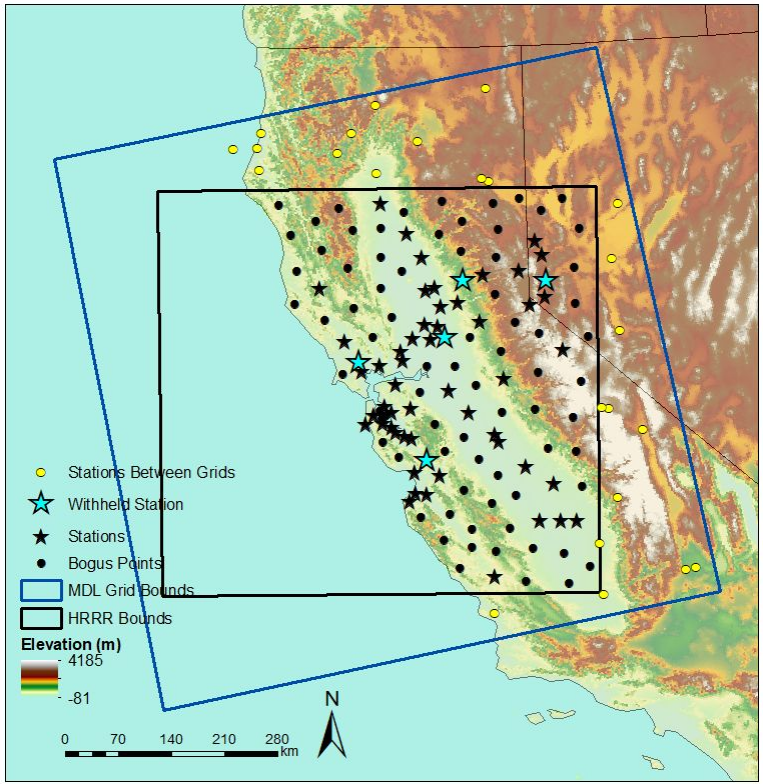
Pseudo Obs Equation Development

- Multiple Linear Regression equations were developed to predict the ceiling height observation at stations in the SFO region for 1600 UTC during stratus and 2300 UTC during non-stratus season.
- Predictors considered: HRRR-based RFs, HRRR model predictors, Random Forest “smart” predictors.
- Satellite predictors ultimately not used due to too much missing data.





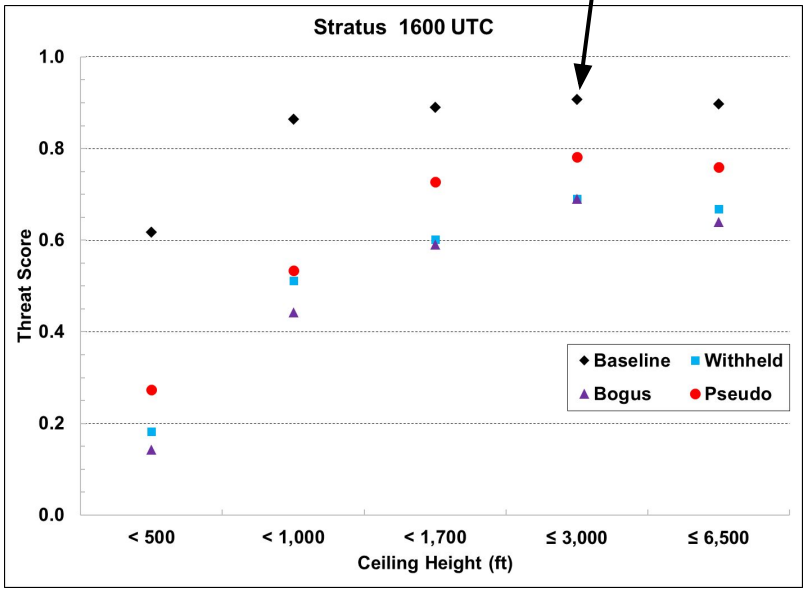
Gridded Ceiling Height Analysis Tests

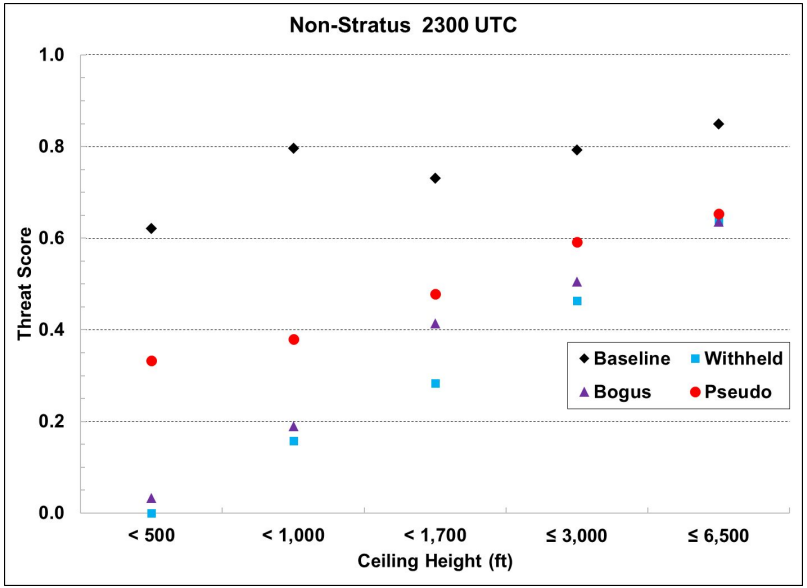


- "Baseline" test - gridded analysis software was run at 1.25 km resolution over an archive period, includes all available observations.
- "Withheld" test - same as "Baseline" but withholding five stations from the analysis (blue stars in figure).
- "Bogus" test - same as "Withheld" run but with pseudo-ob equations applied at bogus points (black dots in figure).

Verification of Analysis Tests at Withheld Stations

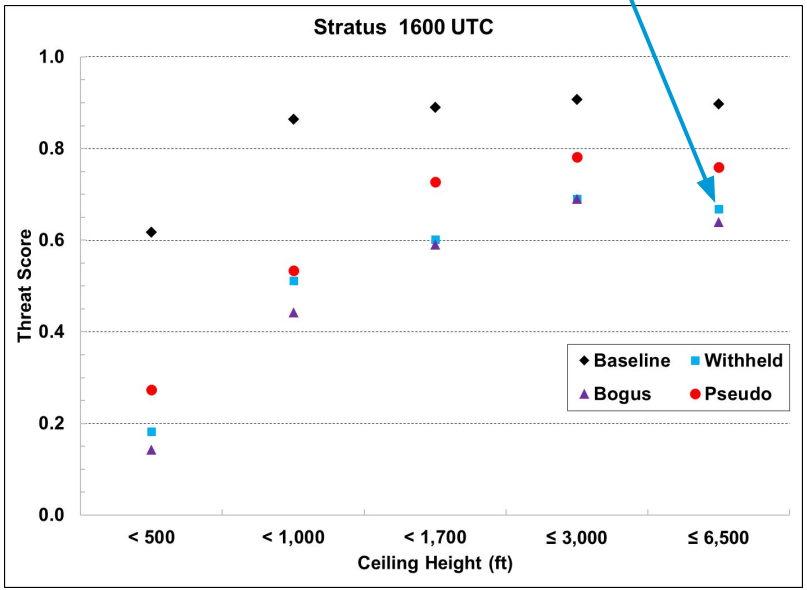
Baseline test (◆) shows best result (as expected) since no stations were withheld from the analysis for this test.

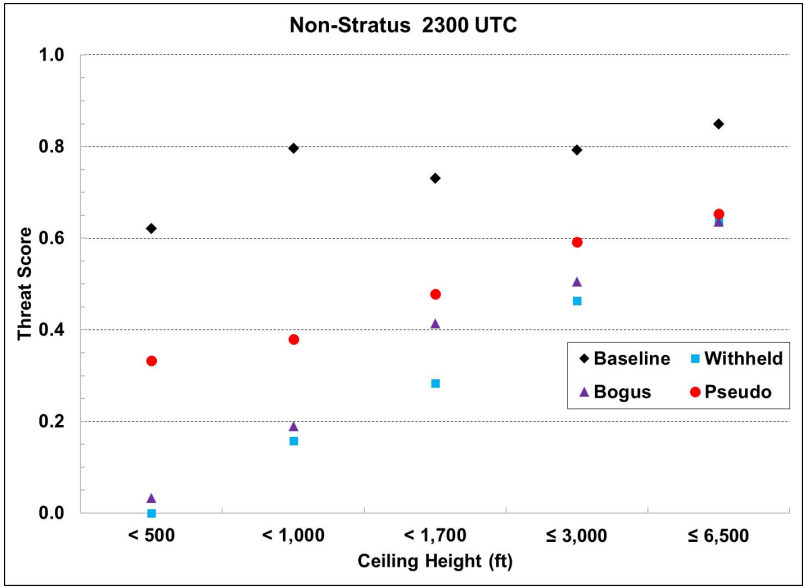




Verification of Analysis Tests at Withheld Stations

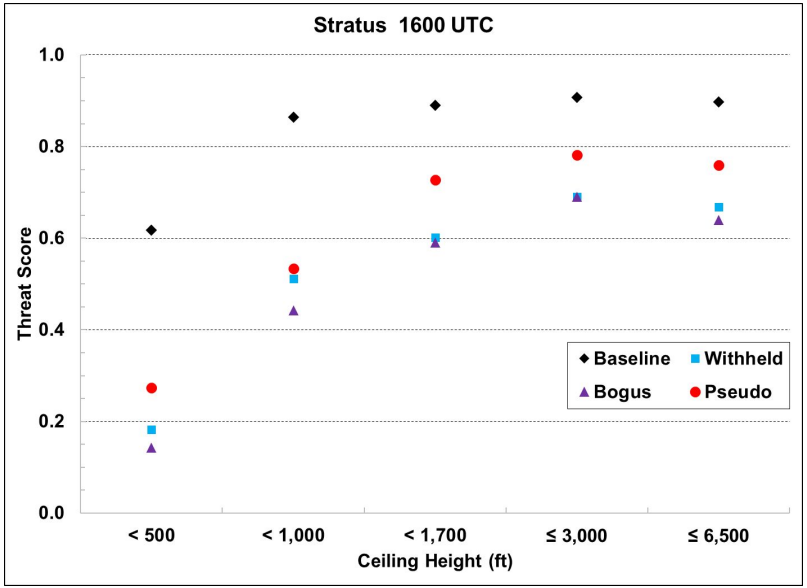
When station observations are withheld (■), results are significantly degraded (again as expected)

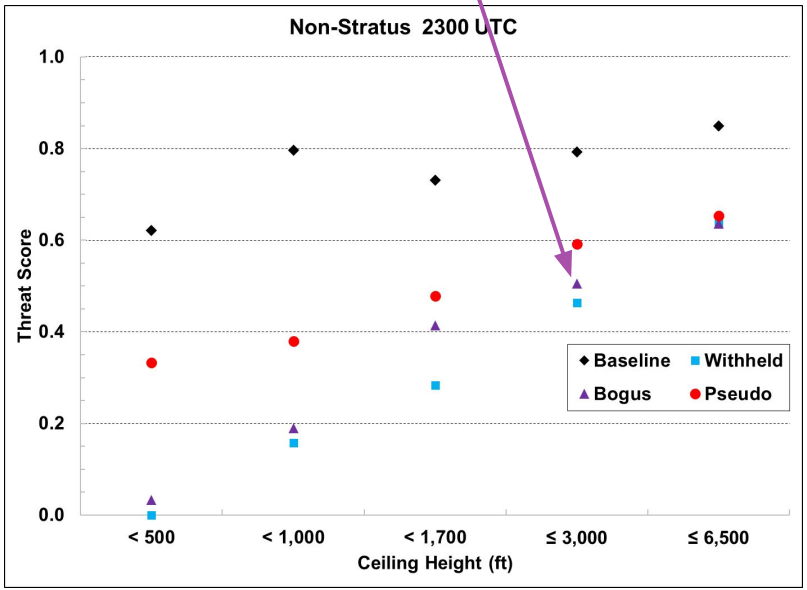




Verification of Analysis Tests at Withheld Stations

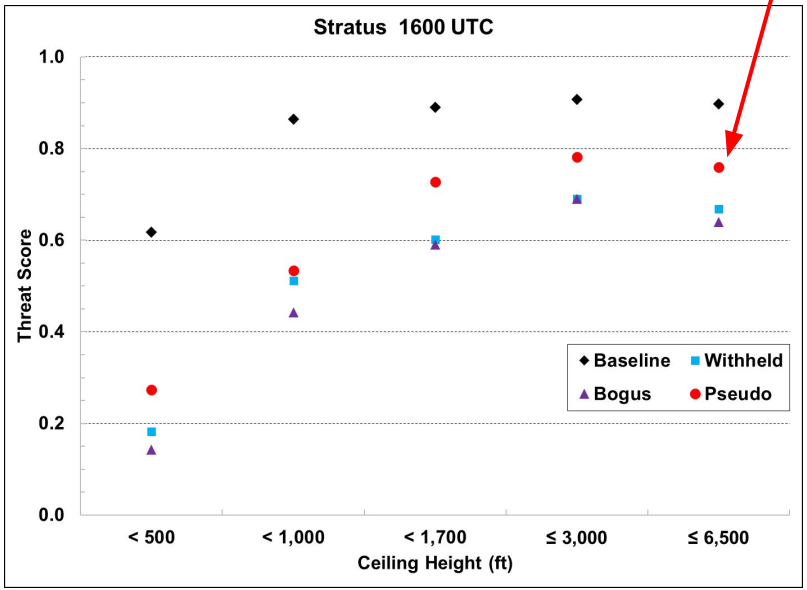
Adding bogus points (▲) did not significantly improve results during stratus season, however notable improvement during non-stratus season.

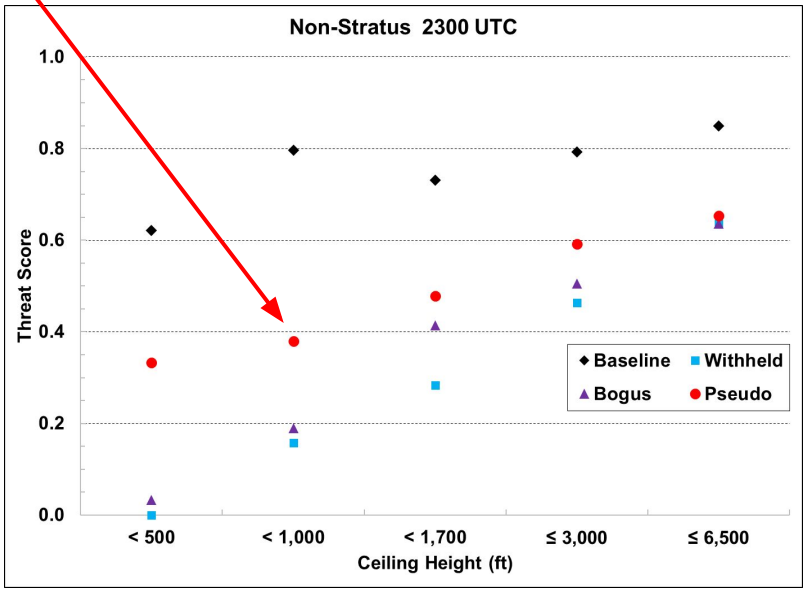




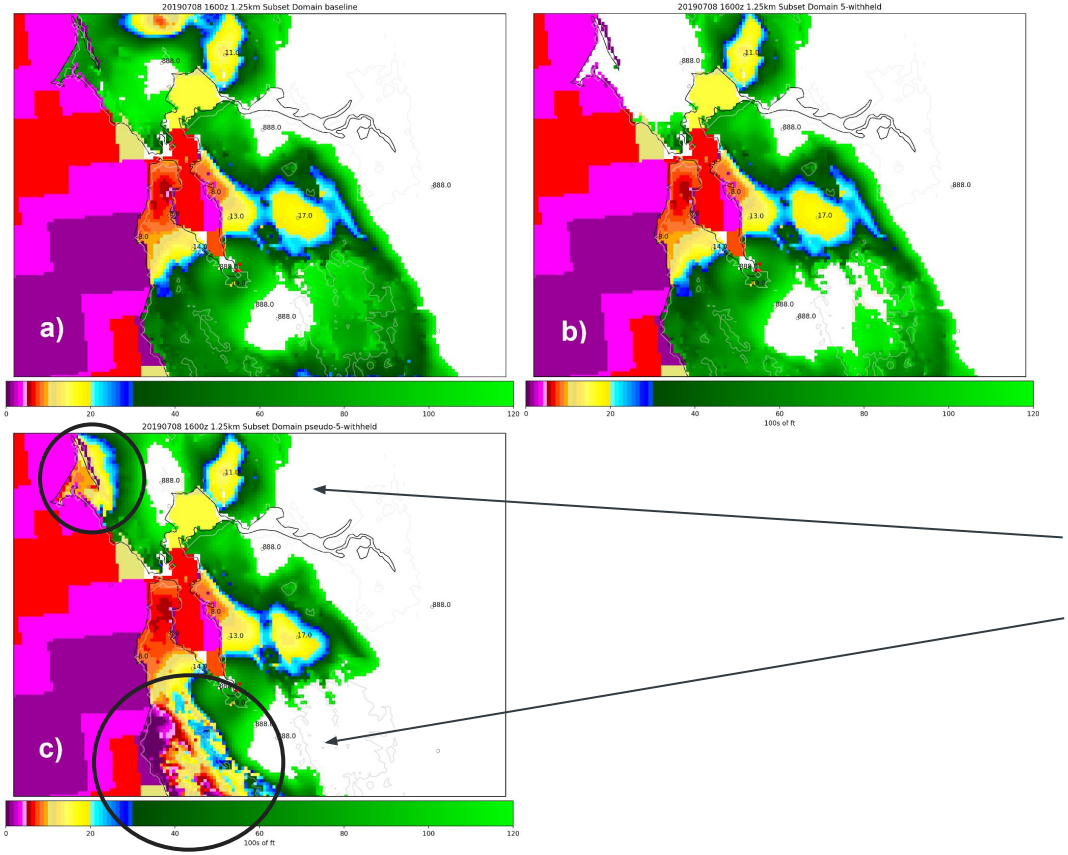
Verification of Analysis Tests at Withheld Stations

Applying pseudo-ob equations directly at the withheld stations (●) is an improvement over both of the withheld tests.





Sample Prototype GLMP Analyses



- Gridded ceiling height analysis for 08 July 2019, 1600 UTC for Baseline run (a), Withheld run (b), and Bogus run (c).
- Biggest differences along coast where bogus point obs are having greater influence.

3. Current Work -
Other Planned Changes (LMP/GLMP v2.5)

LAMP/GLMP v2.5 Upgrade (Early 2023)

- MDL is planning to implement an upgrade of LAMP and GLMP in early 2023 in support of NBM. The upgrade will include:
  - Updated station-based and gridded T/Td guidance to incorporate the HRRR and extend forecast projections to 38 hours.
  - Updated station-based and gridded wind speed/direction/gust guidance to incorporate the HRRR and extend to 38 hours.
- Planned code handoff to NCO this fall, implementation in early 2023.
- Development work for this upgrade is in progress.

4. Future Work

Ongoing/Future Work

- Continue work on development of 15-min GLMP guidance for C&V (funded by FAA).
- Continue work on refining product format options for onset/cessation of flight categories, and incorporate 15-min guidance (funded by FAA).
- Further investigate usability of satellite data to improve GLMP guidance between stations.
- Further investigate AI/ML techniques for improving LAMP guidance.
- Prepare for transition of LAMP/GLMP inputs from HRRR/RAP to RRFS.

Outyear Plans*

- GLMP guidance for Hawaii in support of NBM.
- GLMP cloud top guidance over CONUS in support of NBM (will leverage satellite data).
- GLMP nests for ceiling height guidance over other airports (e.g. ATL, LGA, ORD).
- Assimilation of camera visibility observations into GLMP.
- Cloud base guidance for CONUS.

* All future plans are contingent on funding and should be considered as tentative.

Thank you!

Questions?

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Judy.Ghirardelli@noaa.gov

LAMP Web Page:
https://vlab.noaa.gov/web/mdl/lamp