A Performance Assessment of the National Ceiling and Visibility Analysis Product

Quality Assessment Product Development Team
NOAA/ESRL/GSD

Andrew F. Loughe, Brian P. Pettegrew, Judy K. Henderson,
Joan E. Hart, Sean Madine, Jennifer Mahoney

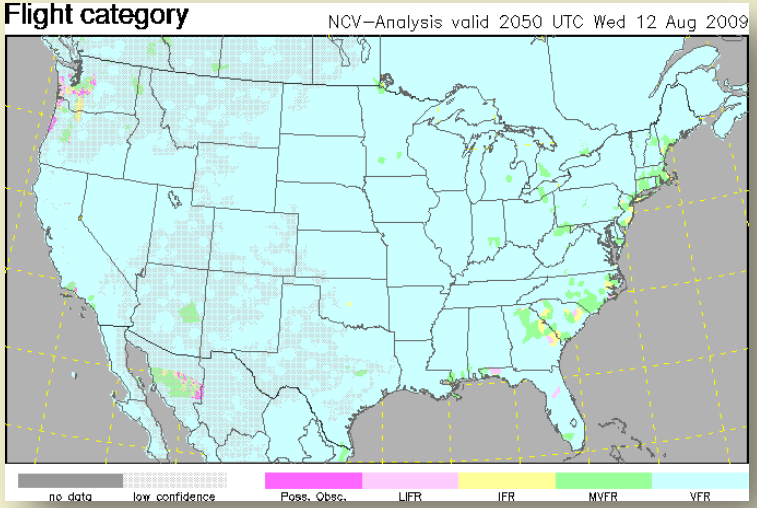
15th Conference on Aviation, Range, and Aerospace Meteorology

NCVA Product Description

A gridded analysis and graphical display tool (via ADDS)

- Provides: **ceiling**, **visibility**, and **flight category**

- Coverage over the CONUS, but not the oceans
- Built on the 5km NDFD grid
- Analysis updated every 5 minutes
- Utilizes over 1,800 METAR stations
- GOES-E,W identifies cloud-free areas
- Confidence field (normal / low)



Purposes of the Evaluation

In the context of pre-flight planning, we set out to answer these questions:

1) What is the **performance** of the NCVA product with respect to that of a baseline analysis (NN-A)?

2) What effect does the ”clearing” **cloud mask** have on NCVA performance?

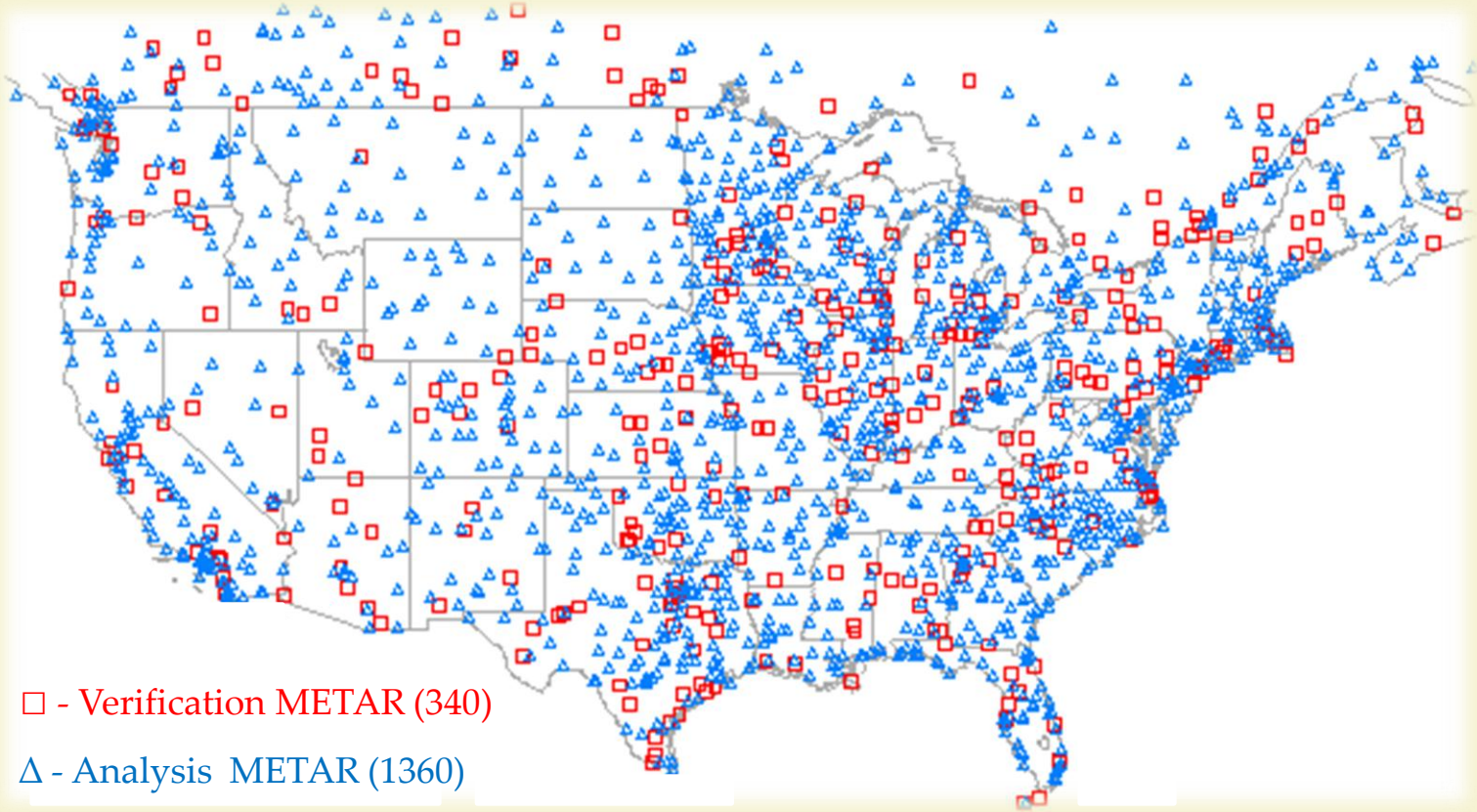
3) Does the **5-minute update frequency** provide a benefit over less-frequent analyses?

4) Does the NCVA perform as well as, and is it consistent with, **manually generated products**?

Cross-Validation Technique

- METARs are used in both the *creation* and *verification* of the NCVA.
- Cross-validation provides an independent set of METARs used for verification:
  - METARs are selectively withheld, facilitating a measurement of how well the analysis performs ***in between*** METAR reporting sites.
- Assumptions:
  - Withholding some METARs has a minimal effect on NCVA quality.
  - Withheld METARs are well distributed, and effectively represent the entire domain.

Sample Cross-Validation METAR Distribution



- **METARs withheld from set #10 runs, 340 stations**
- **METARs included in set #10 runs, 1360 stations**

Baseline Skill: NCVA vs NN-A

- A baseline analysis was created to enable NCVA performance to be compared with performance from a *proxy* for operational planning.

- **DEFINITION:**

  The Nearest-Neighbor Analysis (**NN-A**) is the *analysis* of ceiling and visibility taken from that METAR which is closest to a withheld METAR site, consistent with the cross validation approach.

- **FOR VERIFICATION:**
  - **NN-A:** the actual report from a withheld METAR site is compared to a report from the nearest-neighbor METAR.
  - **NCVA:** the actual report from a withheld METAR site is compared to NCVA output located within a 10 km radius (R10) of the withheld METAR. The analysis point with the *best flight category match* is then used for verification.

Results from the assessment

(summer 2008, winter 2009)

Overall Performance of NCVA

- Overall, the NCVA could add significant value to the planning process compared with the NN-A:

	NCVA vs NN-A Detection Rate	NCVA vs NN-A FARatio
Both Seasons	0.71 vs 0.60	0.25 vs 0.39
Summer (2008)	0.60 vs 0.47	0.31 vs 0.51
Winter (2009)	0.77 vs 0.66	0.22 vs 0.34

  - By **more effectively detecting IFR events** and reducing risk over the CONUS (NCVA Probability of Detection is **0.71 vs. 0.60** for the NN-A).
  - By more effectively **reducing false alarms of IFR events**, resulting in more efficient use of the airspace (NCVA False Alarm Ratio of **0.25 vs. 0.39** for the NN-A), with a lower False Alarm Ratio being more favorable.

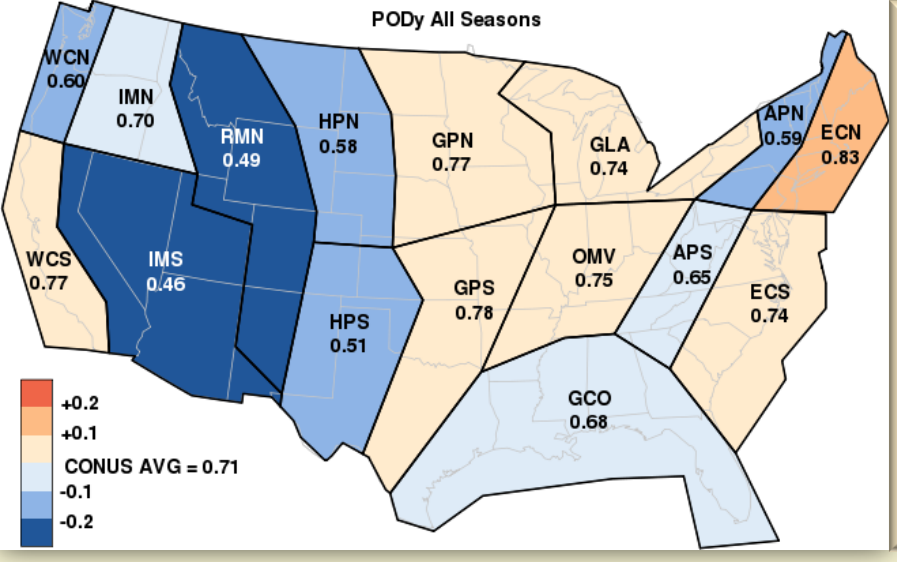
Seasonal Performance of NCVA

- The quality of the NCVA and the NN-A differ during the wintertime (2009) and summertime (2008):

	NCVA vs NN-A Detection Rate	NCVA vs NN-A FARatio
Both Seasons	0.71 vs 0.60	0.25 vs 0.39
Summer (2008)	0.60 vs 0.47	0.31 vs 0.51
Winter (2009)	0.77 vs 0.66	0.22 vs 0.34

  - NCVA has a significantly **higher detection rate of IFR events** in the wintertime than in the summertime (**0.77 vs. 0.60**).

  - The NCVA has a slightly **lower (better) False Alarm Ratio** in the wintertime than in the summertime (**0.22 vs. 0.31**).

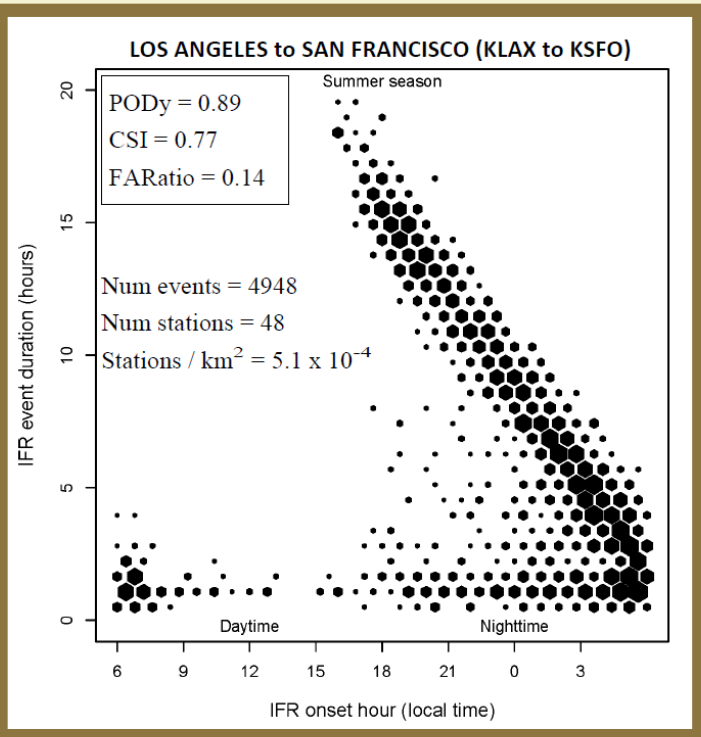


Regional performance (PODy) for all seasons
[color = deviation from CONUS average]

- Relatively high PODy values in the Midwest, East, and Southwest Coast.
- The Intermountain West reflects a significantly lower PODy.

Frequency of IFR event duration vs. onset hour

- Long-duration IFR events are initiated with great frequency along the west coast at night.



Application of the Cloud Mask

- GOES cloud mask data are used to specify "clear" (no ceiling) conditions in regions where METAR data are missing.

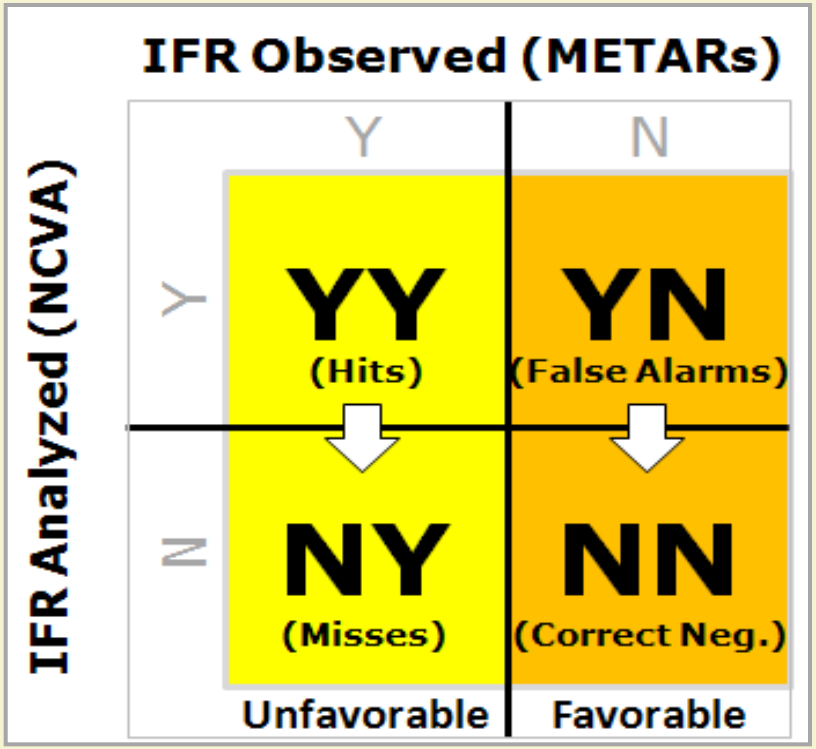
  Satellite data: less than 45 min. old

- The NCVA confidence field provides information on the quality of observations:

  Normal: Close proximity to METAR and/or unambiguous satellite data.

  Low: Greater than normal uncertainty from the observations.

The clearing effect of the cloud mask



Effect of the Cloud Mask

Time Period	Increase in Misses with Application of the Cloud Mask (*Unfavorable*)	Decrease in False Alarms with Application of the Cloud Mask (*Favorable*)	Net Decrease in *Low* Flight Category Confidence Values (re-assignment to *Normal* Flight Category Confidence
Summer and Winter	137 **(0.52%)**	1,356 **(5.87%)**	74,504 (9.26%)

An overall **decrease in false alarms** (**5.87%**) that *outweighs* an **increase in misses** (**0.52%**), resulting in more efficient use of the airspace while only slightly increasing the risk. NCVA risk is still significantly lower than that of the baseline.

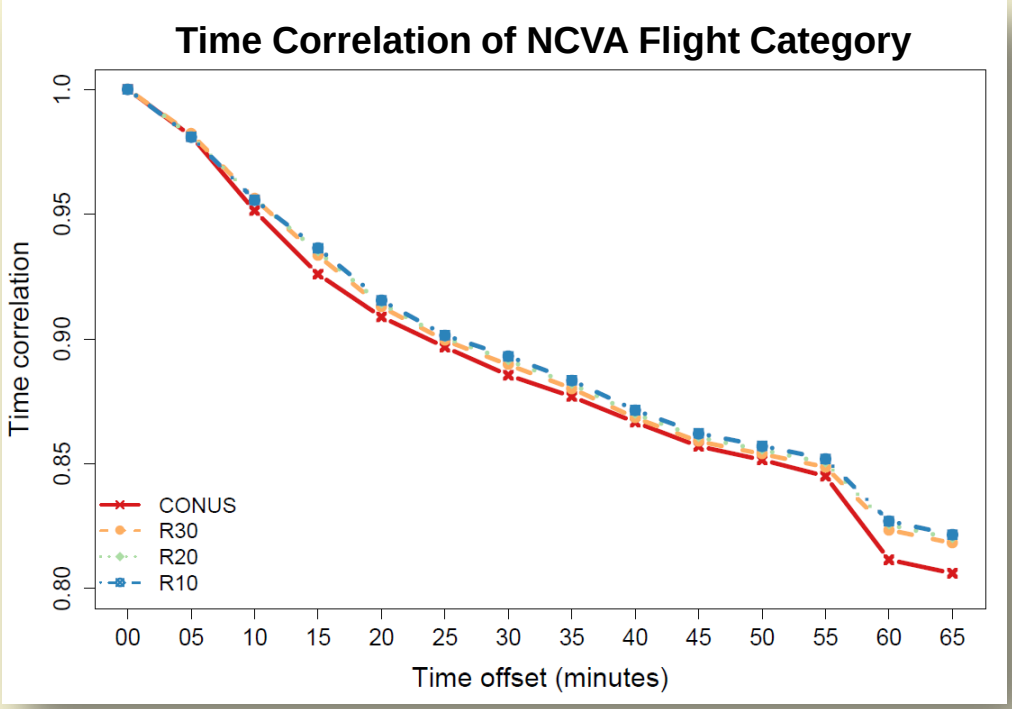
Effect of the Cloud Mask

Time Period	Increase in Misses with Application of the Cloud Mask (*Unfavorable*)	Decrease in False Alarms with Application of the Cloud Mask (*Favorable*)	Net Decrease in *Low* Flight Category Confidence Values (re-assignment to *Normal* Flight Category Confidence
Daytime (excludes 1200 UTC)	28 (0.33%)	503 (6.52%)	72,659 **(24.3%)**
Nighttime (excludes 1200 UTC)	81 (0.72%)	524 (5.52%)	-180 **(-0.054%)**

A measurable difference between daytime and nighttime, as a large number of analysis grid points possessing *low* flight category confidence are actively re-assigned to *normal* flight category confidence during the daytime (**24.3%**), but only a negligible amount change during the nighttime (**-.054%**).

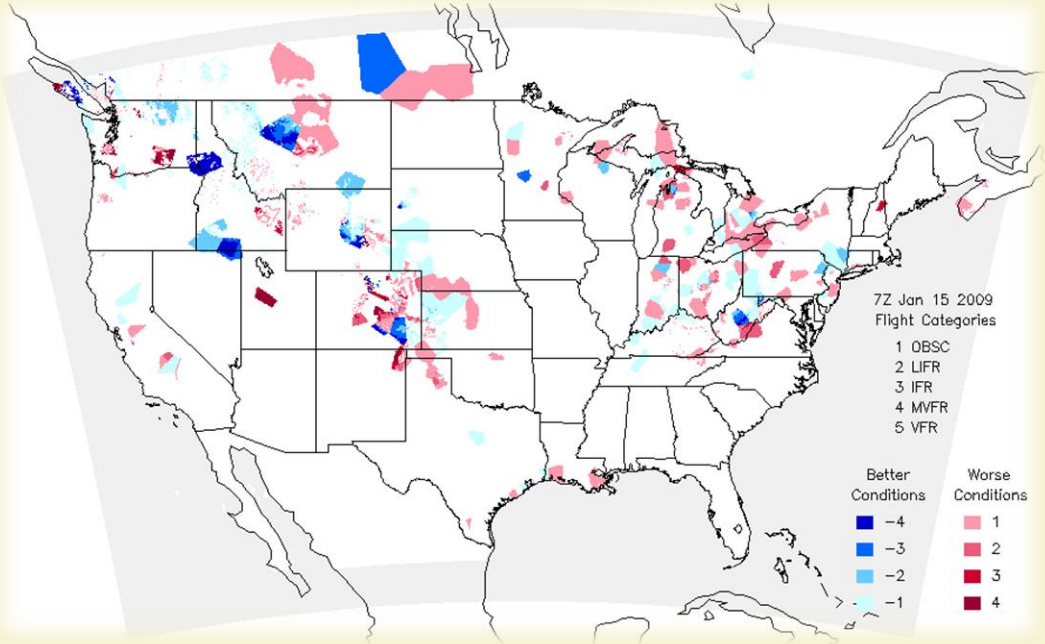
Benefit of NCVA Frequent Updates

- **The Five-minute update** of the NCVA provides information useful to planners as it appears to effectively capture incremental changes in flight category over the CONUS.

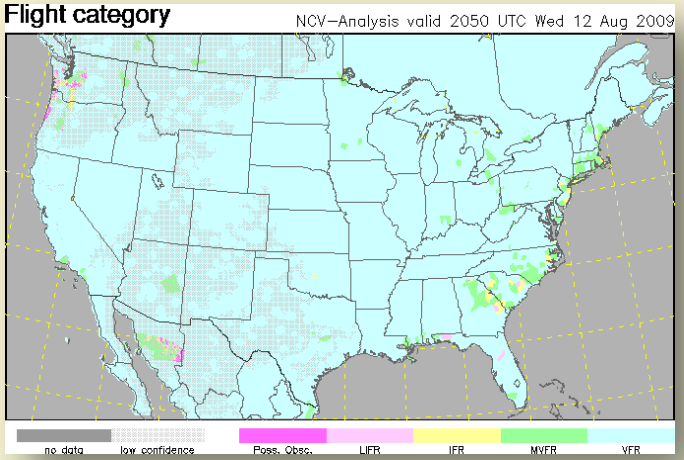


Benefit of NCVA Frequent Updates

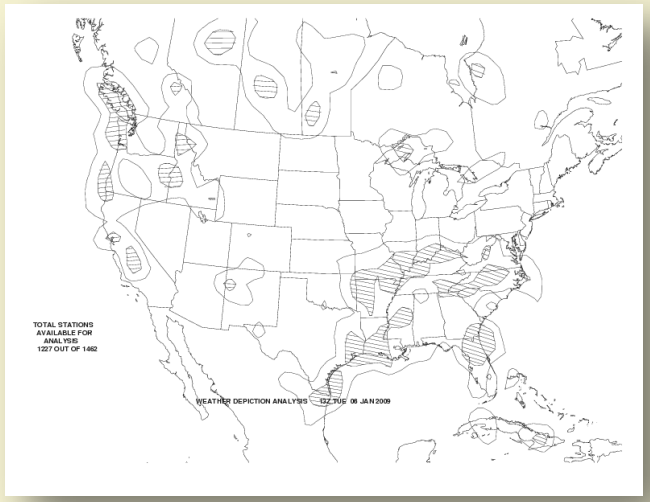
- Linear correlation between an NCVA issuance of flight category to its successor one hour later is **~0.85**, representing a significant change in flight conditions over the CONUS.



Weather Depiction Analysis vs. NCVA



Sample NCV Analysis product

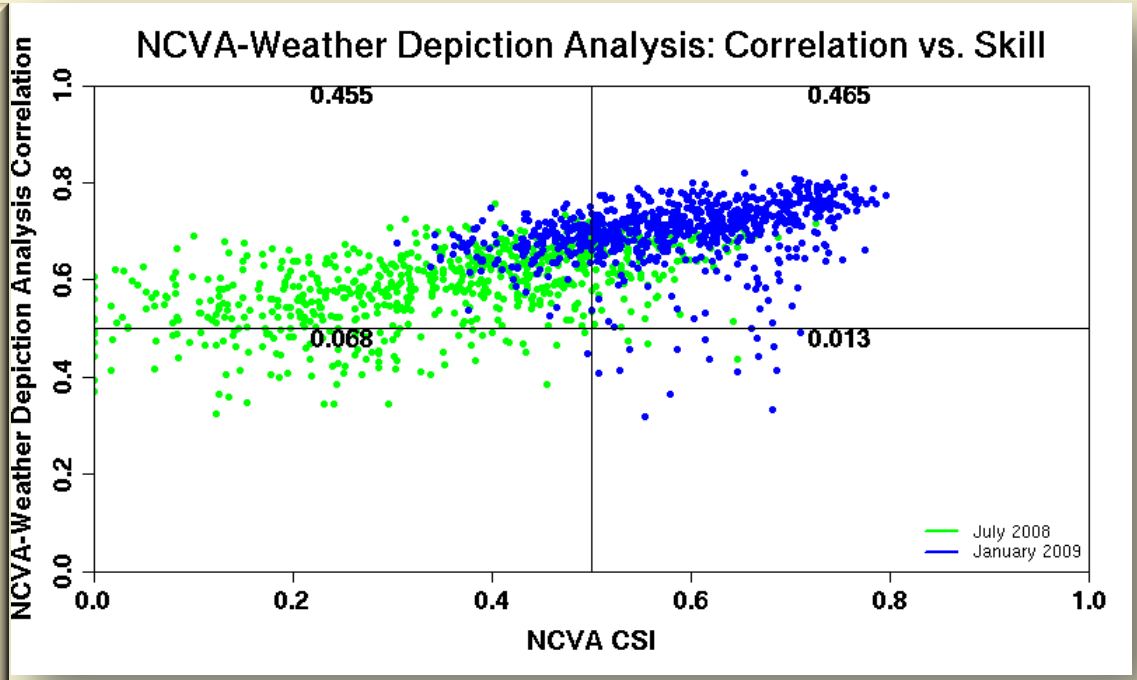


Hourly Weather Depiction Analysis

- NCVA was found to be consistent with the Weather Depiction Analysis:
  - With no suitable way to directly measure quality of the Weather Depiction Analysis, we found indications that NCVA performs at least as well as the Weather Depiction Analysis.
  - NCVA provides more frequent updates than the Weather Depiction Analysis (5-minute vs. Hourly).

Correlation vs. Skill

- Correlation of NCVA to the Weather Depiction Analysis is **>0.6**
- The highest correlation is measured during wintertime when overall NCVA skill is greatest



Brief Summary

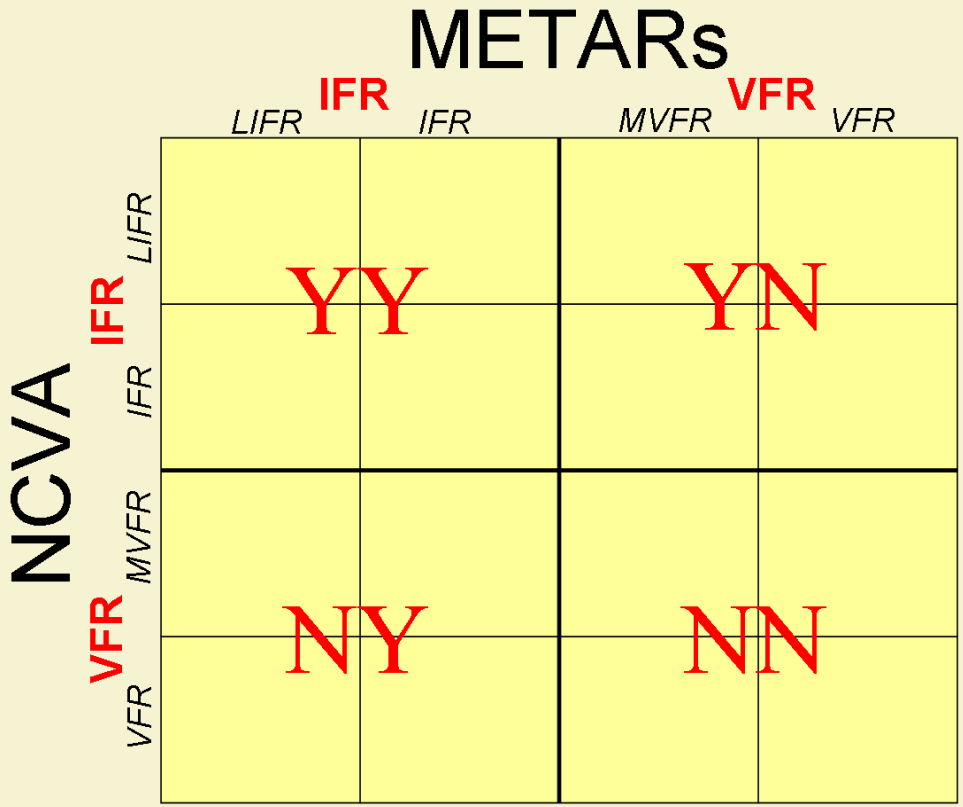
- NCVA is more effective than the NN-A at:
  - Detecting IFR events: **0.71 vs. 0.60**
  - Reducing false alarms of IFR events: **0.25 vs. 0.39**
- From application of the cloud mask: an overall decrease in false alarms (**5.9%**) outweighs an increase in misses (**0.5%**).
- Linear correlation between NCVA issuance and its successor one hour later is **~0.85**. We measured steady and significant changes throughout the hour.
- NCVA and the weather depiction analysis have an overall correlation greater than **0.6**, with the highest correlation measured in the wintertime when NCVA skill is greatest.

The End

This research is in response to requirements and funding provided by the Federal Aviation Administration. The views expressed are those of the authors and do not necessarily represent the official policy and position of the U.S. Government.

Additional slides…

Dichotomous Assessment



4 X 4 contingency table for categorical flight conditions for the NCVA product vs. METAR observations (in italics). A reduced 2 X 2 (dichotomous) contingency table is labeled in red within the context of the larger 4 X 4 contingency table.

Statistics calculated in the dichotomous assessment

Statistic	Formula
PODy (Probability of Detection for Y, Hit Rate, also called Detection Rate)	YY / (YY + NY)
PODn (Probability of Detection for N)	NN / (NN + YN)
Bias	(YY + YN) / (YY + NY)
FARatio (False Alarm Ratio)	YN / (YN +YY)
FAR (False Alarm Rate)	1 - PODn
TSS (True Skill Statistic)	PODy + PODn -1
CSI (Critical Success Index, Threat Score)	YY / (YY + YN + NY)

Continuous Assessment

Statistic	Formula
Sample Size	n
NCVA Value	N
Observed Value	O
Mean value of N and O	$\overline{N} = 1/n\sum_{i=1}^{n} N_i \quad ; \quad \overline{O} = 1/n\sum_{i=1}^{n} O_i$
Second moment quantities	$\overline{NN} = 1/n\sum_{i=1}^{n} (N_i * N_i) \quad ; \quad \overline{OO} = 1/n\sum_{i=1}^{n} (O_i * O_i)$ $\overline{NO} = 1/n\sum_{i=1}^{n} (N_i * O_i)$
Mean Error (Bias)	$\overline{N} - \overline{O}$
Root Mean Square Error	$\sqrt{\overline{NN} - 2 * \overline{NO} + \overline{OO}}$
Standard Deviation $_{N, O}$	$\sqrt{\frac{n * (\overline{NN} - \overline{N}^2)}{(n-1)}} \quad ; \quad \sqrt{\frac{n * (\overline{OO} - \overline{O}^2)}{(n-1)}}$
Covariance	$\frac{n * (\overline{NO} - \overline{N} * \overline{O})}{n-1}$
Correlation	$\frac{\text{Covariance}}{(StdDev_N * StdDev_O)}$

Statistics (computational form) used for studying continuous measurement error of the NCVA ceiling and visibility attributes.