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AUTOMATED REAL-TIME ANALYSIS OF CEILING AND VISIBILITY ON THE NATIONAL SCALE

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1. INTRODUCTION

The FAA Aviation Weather Research Program's (AWRP) National Ceiling and Visibility Product Development Team (NCV PDT) has developed automated analysis and forecast products describing ceiling and visibility conditions over the continental United States (CONUS). In addition, the PDT is beginning work toward similar products for Alaska.

Adverse ceiling and visibility conditions contribute to a large portion of the weather related accidents in the general aviation community. The NCV analysis product incorporates observational data from both Automated Surface Observing System (ASOS) and Geostationary Operational Environmental Satellite (GOES) imagers. At present, GOES imager data are used to outline the extent of clear and cloudy conditions, while ASOS data is used to determine cloud ceiling height and surface visibility.

This paper will discuss the use of cloud masking, related GOES products, interpolation techniques, and confidence in the analysis products current system methodology, performance and future development.

2. OVERVIEW OF THE CURRENT NCV ANALYSIS PRODUCT

The NCV analysis product is being developed to provide real-time conditions of ceiling height, visibility, and flight category to operational forecasters, pilots, and other end-users in an automated system for continuous use throughout the day. The product is being developed with automation as a key component of the system. No human augmentation of the product is being performed. The system relies completely on the automation of ingesting, computing and disseminating of data.

<u>Gridded Analyses</u>

The current NCV analysis system provides gridded analyses of cloud ceiling height, visibility, and flight category. Each of the products is currently displayed using the RUC forecast model native grid resolution (currently 20 km). This is used in the accompanying NCV forecast product (Herzegh et al., 2005). Most METAR reports are provided just before the top of the hour, but special METAR reports can be

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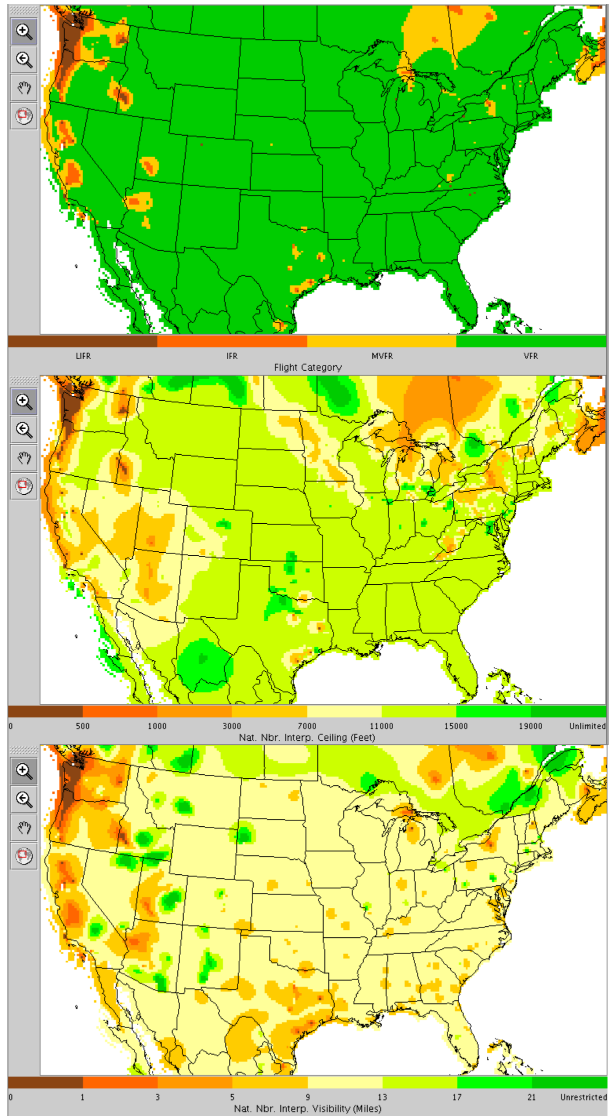

Figure 1. Current conditions reported by the NCV analysis product. (Top) Flight Category (Low IFR, IFR, Marginal VFR, VFR) determined by combination of ceiling height and visibility. (Middle) Ceiling height in feet AGL. (Bottom) Visibility in statute miles. Experimental product display is available at www.rap.ucar.edu/projects/cvis.

received at any time. Since special METARs are reported when extreme changes in ceiling height and visibility occur ceiling below 12,000 feet AGL and the cloud mask determines the grid point is clear, the grid point , it is important to relay this information to the user in a timely fashion. This results in the analysis product being updated every 15 minutes to provide the most current C&V conditions. The graphical display currently provides users the opportunity to overlay METARs and TAFs on the gridded analysis products. An example of the current ceiling height, visibility, and flight category analysis products generated by the NCV experimental product over the CONUS is shown in Fig. 1.

Interpolation of METAR reported conditions

Quantifying the ceiling and visibility within the regions between METAR stations is a major challenge for the NCV analysis system. A method is needed to characterize the conditions between these stations since large spatial gaps exist between ASOS stations around the country. A first approach to characterizing the ceiling height and visibility is to interpolate the conditions from the METAR stations to the intervening areas. Interpolation techniques that have been used include (i) nearest neighbor, (ii) natural neighbor, and (iii) Kriging.

Preliminary evaluation of the three different interpolation techniques showed only slight differences in performance for each method. The nearest neighbor technique scored the best, but the other two techniques scored within the statistical margin of error. Since the natural neighbor interpolation technique is considered the most visually appealing, the NCV analysis product is displayed using this technique.

3. AUGMENTING CEILING HEIGHT ANALYSES USING GOES SATELLITE DATA

Since a large portion of the CONUS does not have surface observations of ceiling and visibility, GOES satellites can provide limited information for areas between surface observations. Though satellites cannot determine ceiling height or visibility, they can provide us information on whether clouds exist. Automating the detection of clouds using satellites has proven to be a difficult challenge. Cloud detection is challenging for many reasons including (i) satellite viewing angle over the CONUS, (ii) limited use of the visible channel, (iii) effects of solar angle on specific satellite channels, and (iv) seasonal and diurnal changes in clear sky background data.

Current NCV Cloud Mask

The current NCV analysis product uses a combination of GOES-10 (west) and GOES-12 (east) to provide a daytime cloud mask created using GOES infrared (IR) channels (3.9 μm and 10.7 μm), the visible channel and channel derived components. The cloud mask is generated using a combination of threshold and comparison tests of the above mentioned components. Examination of the previously used cloud mask in the analysis system showed below satisfactory results in the nighttime and terminator (solar angle less than 15°) cloud masking capabilities. Until future improvement in the NCV product cloud detection algorithm, a cloud mask is only generated for daytime use and is only used to augment the METAR interpolated ceiling height field. The cloud mask is also only used to augment ceiling heights to 12,000 feet AGL for grid points located away from ASOS stations. A ceiling height of 12,000 feet AGL is used since it is the ceiling determination limit for the majority of METAR sites. This height may be adjusted as more ASOS stations across the CONUS are converted over to new instrumentation allowing for ceiling heights to be detected up to 25,000 feet AGL. This approach attempts to clear out areas between METAR stations that appear cloud free according to the cloud mask. If a METAR reports a ceiling below 12,000 feet AGL and the cloud mask determines the grid point is clear, the grid point remains at the ceiling height determined by the METAR. Fig. 2 shows a comparison of ceiling height using natural neighbor interpolation of METARs with and without the augmentation of ceiling heights with satellite data.

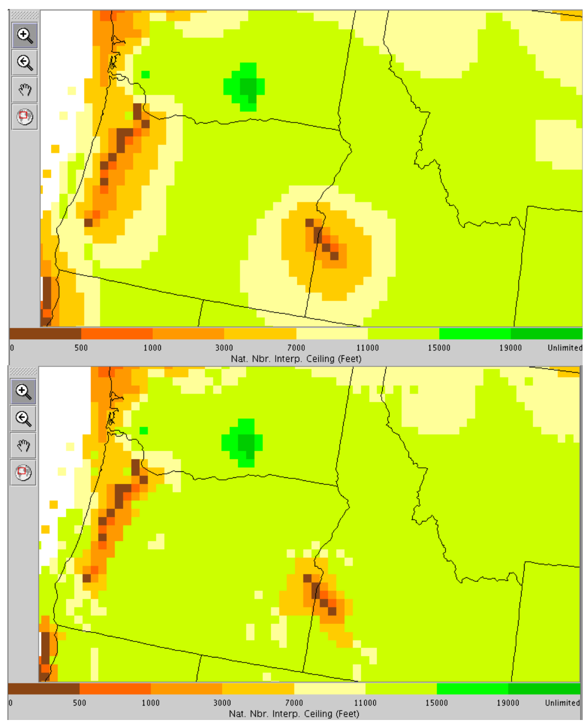

Figure 2. Comparison of gridded analysis of ceiling height using strictly interpolated METAR data (Top) and ceiling height using interpolated METAR data augmented by satellite cloud mask (Bottom).

The cloud mask is not currently being used to invoke any quality control on the METAR stations. It is only being used to confirm ceiling heights near the ASOS stations and augment ceiling heights interpolated from the METAR data distant from the stations. For grid points near the ASOS site but not corresponding directly to the METAR, a strict threshold is applied disallowing low ceiling heights to be altered. The resulting ceiling height field from combining the GOES cloud mask shows slight adjustments to the underlying ceiling height fields around the edges of areas of cloudiness.

Planned Improvement in Cloud Masking

The NCV PDT is currently collaborating with members of the Advanced Satellite Aviation Weather Products (ASAP) initiative to improve cloud masking over the CONUS. The initiative has sought to make satellite derived cloud and weather products available to the AWRP PDTs for integration into forecasting algorithms for the aviation community (Thomas et al., 2004). The ASAP group is currently providing information applicable to the NCV PDT in a CONUS cloud product with information on whether cloud is detected as well as a corresponding cloud top pressure (CTP) field. This product is currently being evaluated for incorporation into the analysis product. The NCV PDT is concurrently examining other techniques such as the Bi-spectral Threshold and Height (BTH) method (Jedlovec and Laws, 2003). The aforementioned cloud mask techniques resolve some of the complexities in automated satellite cloud detection. Applying such techniques in the future will allow for augmentation of ceiling heights regardless of time of day or location.

4. CONFIDENCE IN THE NCV ANALYSIS PRODUCT

A recent addition to the NCV Analysis Product is a confidence field which has been added in an experimental mode to assist the user in their determination of adverse ceiling and visibility conditions. The confidence field is currently designed as more of a diagnostic tool and is not currently being displayed to the end-users. Confidence is determined using the ceiling height field, cloud mask and distance from the closest ASOS station for each grid point. The system designates a value of confidence for each grid point based on the availability of each component and indication of ceiling height and cloud detection. Tables 1 and 2 show a breakdown of confidence categories. Each table is listed from high to low confidence. These tables show that confidence is weighted higher in areas close to ASOS stations. The confidence field is also weighted higher for reports of no ceiling/clouds. Since METAR stations only report ceilings to 12,000 feet AGL, the system determines a higher confidence when the satellites determine that clouds are present and the METAR indicates no ceiling below 12,000 feet. Figs. 3 and 4 show examples of the current confidence field being displayed on the experimental product.

Prior to providing the confidence field to the end-users, it is planned to simplify the categorical breakdown of confidence to allow for easier understanding of the field. Adding new components to the system would permit for more comparisons between such components allowing for greater confidence to be determined.

Confidence levels with METAR and GOES Data			
Confidence Level	Observations		Distance Limit
	GOES	METAR	
High	No	No	Close
↓	Cloudy	Ceiling	Close
	No	No	Far
	Cloudy	No	Close
	Cloudy	Ceiling	Far
	No	Ceiling	Far
	Cloudy	No	Far
Low	No	Ceiling	Close

Table 1. Confidence levels NCV analysis product determined by GOES and METAR data.

Confidence levels with METAR data only			
Confidence Level	Observations		Distance Limit
	GOES	METAR	
High	--	No	Close
↓	--	Ceiling	Close
	--	No	Far
Low	--	Ceiling	Far

Table 2. Confidence levels for NCV analysis product determined by METAR data only.

5. FUTURE IMPROVEMENTS

Research and development are ongoing to improve the performance of the NCV analysis system. Investigation of new components and techniques are aimed at improving the detection of adverse conditions along with decreasing the false alarm rate under such conditions. Future improvements include, but are not limited to, (i) improved gap filling for areas of sparse METAR reports, (ii) smarter interpolation of analysis product components, (iii) supplementary surface observations and (iv) the addition of new overlays to assist the user in evaluating current conditions (e.g. AIRMETs). In addition, we will be developing a similar analysis system for Alaska.

Our goal is to provide the most pertinent information to the user with regards to ceiling and visibility conditions. Additions to the NCV analysis product are evaluated with the amount of computing time needed for the component in mind. A balance must be maintained between product accuracy and the need to update and distribute it in a timely fashion.

Gap Filling

A first attempt at gap-filling of areas with sparse surface observations has been added to the NCV system by augmenting ceiling heights using satellite data. Currently, the cloud mask used in augmenting the interpolated ceiling height field is used internally and is not displayed to the user. Improved satellite information and the addition of NEXRAD data could improve the analysis product. Neither satellite nor NEXRAD directly measure ceiling height or visibility but could aide in the interpolation of the known surface conditions. The current cloud mask does not try to classify cloud type. The ability to distinguish Stratus and Fog from other cloud types and background features has been shown possible by Lee *et al.* (1997). Using such a cloud product could help improve techniques used in interpolating ceiling and visibility conditions.

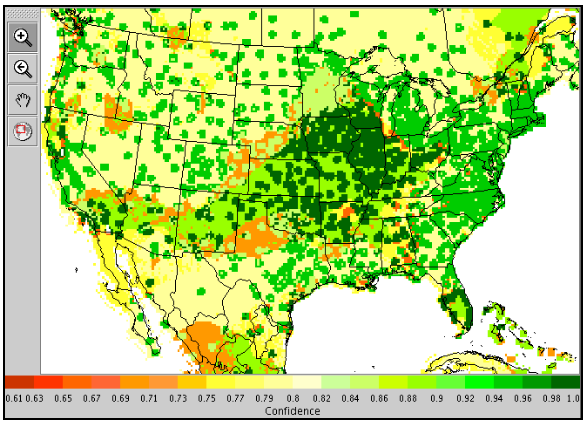

Figure 3. Daytime confidence field for NCV analysis product created using GOES and METAR data.

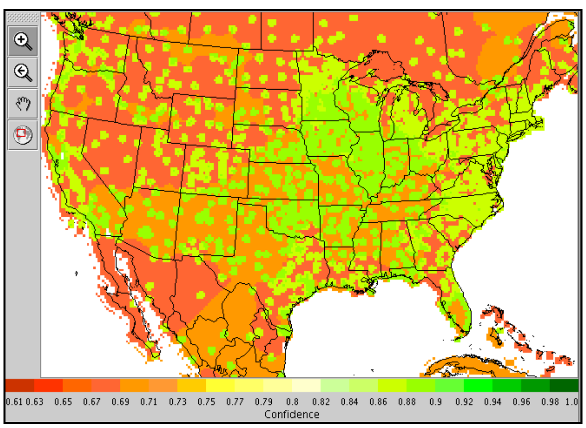

Figure 4. Nighttime confidence field for NCV analysis product created using only METAR data.

A different attempt at gap filling is being researched at the Naval Research Laboratories (NRL) using a data mining method called Knowledge Discovery from Databases (KDD) to assess ceiling height (Bankert et al., 2004). This approach uses satellite and numerical model data to provide estimates of cloud ceiling height for areas where surface observations are unavailable.

<u>New Overlays for Evaluation of C&V Conditions</u>

The current NCV analysis product allows for concurrent examination of gridded analyses, METARs and TAFs. This is done to provide users a single source for viewing ceiling and visibility conditions around the CONUS. Since these products are not the only sources of information on C&V conditions, the ability to view other sources of information including AIRMETs, SIGMETS will allow the user to better understand current conditions.

6. SUMMARY

This paper outlines the current NCV automated analysis product and research toward improved detection of adverse C&V conditions. The product is being developed to improve the availability of current C&V information for the general aviation community.

Satellite data is incorporated into the automated system to augment ceiling heights in areas sparse of surface observations. Future work is aimed at improving the cloud detection capability of the system to further improve the ceiling height analysis product.

A confidence field is being developed to allow for operational forecasters, pilots, and other end-users to help in their determination of adverse C&V conditions.

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