3.2 DEVELOPMENT OF AUTOMATED
NATIONAL CEILING AND VISIBILITY PRODUCTS:
SCIENTIFIC AND PRACTICAL CHALLENGES, RESEARCH STRATEGIES, AND FIRST STEPS

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1. INTRODUCTION

Over the period 1989 though 1998, the hazards associated with adverse ceiling and visibility conditions claimed the lives of 1,685 people (averaging over 168 per year) within the U.S. general aviation and charter/air taxi communities[1]. Though the numbers may vary from year to year, many others are subjected to sudden, untenable risk through inadvertent encounters with adverse ceiling and visibility (C&V) conditions, and perhaps thousands more are disrupted by the inherent uncertainty in C&V forecasting and communication at the current state of the art. Overall, poor C&V conditions are cited as a contributing factor in over 35% of all weather-related accidents in the U.S. civil aviation sector[1].

The National Ceiling and Visibility (NCV) research and development program outlined here was established in March, 2001, to help address the aviation safety impacts outlined above. The effort is anchored by the programmatic focus and support of the FAA's Aviation Weather Research Program (AWRP), whose recent work is described in this volume by Kulesa et al. (2002). The NCV program explores the use of observations, numerical modeling, computer automation, and targeted research into key problems in C&V phenomenology. The program grew from the foundation laid by a highly successful joint development effort sponsored by FAA/AWRP, NASA, and the Naval Research Laboratory.

The impact of adverse C&V conditions on the viability and safety of military aviation can be severe as well, particularly where low-altitude stealth, search and rescue, carrier operations, and remotely-piloted operations are involved. Advantageous leveraging between NCV and the Naval Research Laboratory at Monterey (NRL) makes use of shared interests and complementary research expertise of benefit to both civil and military aviation.

In addition to the safety impacts cited above, adverse C&V conditions can strongly reduce the efficiency of terminal area traffic flow. AWRP's companion Terminal Ceiling and Visibility (TCV) program addresses means to minimize that reduction in efficiency and serves as an important collaborator for NCV.

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1 Based upon information drawn from the National Transportation Safety Board Accident Database.

2. DEVELOPMENT STRATEGY OVERVIEW

Current operational C&V forecasts are typically communicated through routine area forecasts (FAs), related AIRMET bulletins focused toward small aircraft, terminal area forecasts (TAFs), and through commercially-available meteorological briefing services. These sources serve an important function, and at the same time leave needs and opportunities that automated tools, frequently-updated gridded products, and web-based display can help address.

NCV initially conceives and supports two product families:

- Gridded analyses of current ceiling, visibility and flight category conditions with ready access to supporting data overlays providing additional information if needed or desired. The concept here is to provide rapid (15 min) updates of current C&V conditions in graphical form while incorporating tools that allow concurrent examination of METARs, TAFs, AIRMETs, and satellite and NEXRAD imagery.
- Gridded 1-12 h forecasts of ceiling, visibility and flight category. The NCV forecast product is formulated as a consensus among a variety of parallel forecast techniques comprised of numerical modeling and observations-based approaches. The forecast product is updated hourly.

NCV products are targeted for operational use directly by the pilot, dispatcher, controller, and other end-user. Since automation is key to enabling frequent product updates and round the clock operation, our work relies upon unattended, computer-aided techniques. These include *(i)* expert system methods to conditionally manipulate data inputs and manage functional interactions among them, and *(ii)* fuzzy logic techniques to formulate a consensus product (*e.g.*, analysis, or forecast), generally based upon the selective merging of individual data and product sub-elements.

3. OBSERVATIONS AND THE ANALYSIS PRODUCT

The challenge to C&V forecasting begins with the difficulty of observing and representing present conditions. The analysis of present conditions given by the current NCV prototype CONUS product is illustrated in Fig. 1. A secondary analysis product developed in collaboration with NRL targets the southern California region and is accessible through the NCV website cited in the figure caption.

A variety of factors come into play in accommodating best use of C&V observational data, and we summarize several of the key issues here:

- Ceiling and visibility observations are essentially distributed point (or small area) samples, and this leaves large areas between ASOS (METAR) or other operational measurement sites essentially unobserved.
- The behavior of both ceiling and visibility demonstrates high spatial and temporal variability in many situations. Thus, the conditions across unobserved (or under-observed) regions can vary dramatically, and variable conditions within those unobserved regions can be critical to a meaningful representation of C&V on a regional scale.
- Terrain influences can induce very strong influence on C&V through occurrence of features such as low valley fog, capping mountain cloud, etc.
- Area measurements such as satellite imagery, while critically important, can not define or resolve ceiling or visibility outright. Satellite observations *do* offer means to cross-check, edit or improve upon certain aspects of surface observations, however. For example, cloud free conditions above and around an ASOS station yield reason to take the ceiling at that point and time as 'unlimited' even though the ASOS station itself would likely report a 12K' ceiling based on ceilometer measurements.

To improve the representativeness of our prototype analysis product, we plan the sequence of automated processing and analysis steps outlined schematically in Fig. 2. New elements of that process not yet implemented are outlined in the four items below:

<u>Supplementary Observations.</u>

To maximize the quality and number of surface observations we augment ASOS METAR data with that from real-time state or local networks. This effort requires careful attention to quality control of the non-ASOS data and understanding of all aspects of the instrumentation in use. It is clear that some (perhaps much) non-ASOS data may be unacceptable due to uncertain quality control or poor instrument performance, and these data must be rejected to assure that they do not diminish the impact and quality of the primary METAR data.

<u>Gap Filling.</u>

The analysis process will utilize IR and visible satellite data and NEXRAD data to help fill or partially characterize the 'gaps' between ASOS or other surface observing sites. While the satellite and NEXRAD information will not be sufficient to unambiguously establish conditions within the gaps, in many cases it should enable improvement in the representativeness of interpolated data in the gap area. The GOES low cloud product, for example, could potentially be useful in this application.

<u>Smart Interpolation.</u>

The high-resolution analysis grid is populated by data interpolated from METAR sites. The interpolation procedure itself is important to preserving the METAR information with minimal alteration or distortion. Our concept for smart interpolation follows from the work of Forsythe et al. (2000), who showed that an interpolation procedure for cloud base height using interpolation pairs from within the same cloud classification field outperformed nearest-neighbor interpolation. This approach reduces the instance of interpolating across dissimilar regions. We plan to explore this form of smart interpolation, as well as further extensions that consider other criteria such as large-scale terrain influences or possibly strong NEXRAD reflectivity gradients.

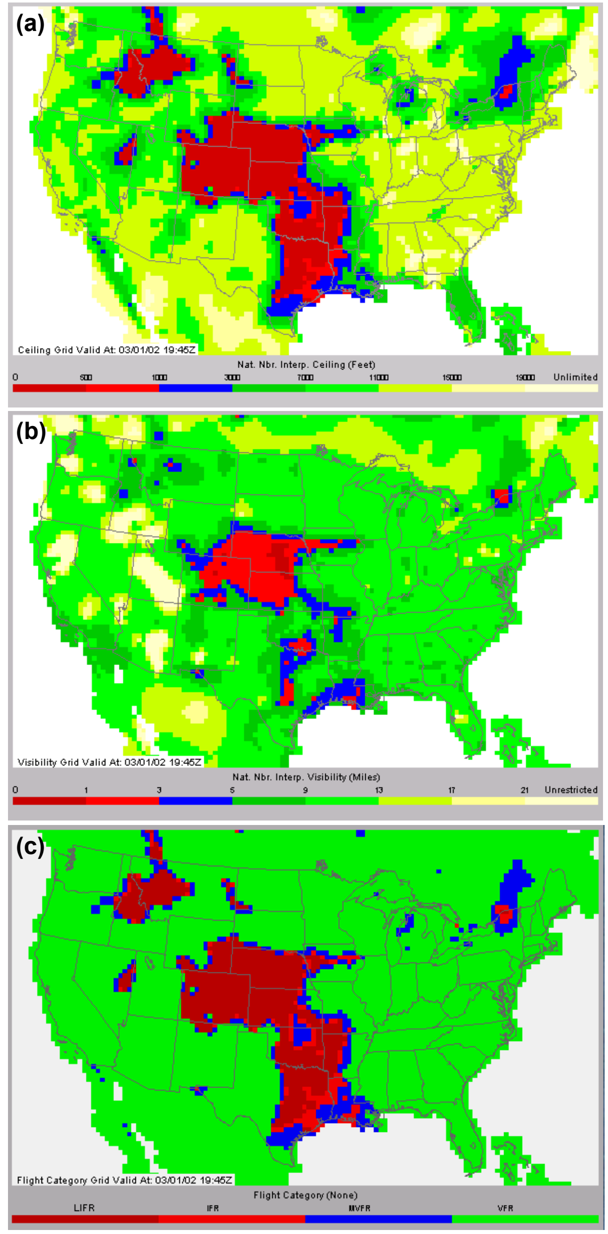

Figure 1. *Current conditions analysis from the NCV prototype display during a major snow storm in the central U.S. (a) Ceiling in K' AGL.. (b) Visibility in statute miles. (c) Flight Category (Low IFR, IFR, Marginal VFR and VFR) as determined from the values in (a) and (b). Prototype display is continuously accessible at www.rap.ucar.edu/projects/cvis/index.html.*

<u>Indeterminate Conditions and Confidence Metrics.</u>

Current practice in the prototype system is to paint quantified ceiling and visibility present condition values

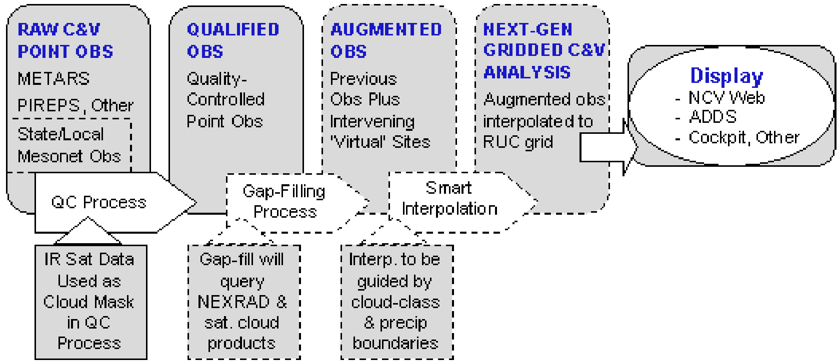

Figure 2. *Schematic representation of NCV point observation analysis system components in use today (solid outlines) and those planned for future use (dashed outlines). Input data are shown in the box at upper left. Processing steps are shown by unshaded arrows and yield the sequence of input data modifications shown from left to right. The reference to ADDS at far right regards the FAA Aviation Digital Data Services website.*

across the full U.S. area display. However, we recognize that there are places (typically gap areas) and times when we have little information, or questionable information, on the status of current conditions. It is prudent to consider these areas as conditionally indeterminate, requiring added caution on the part of the aviation user. By definition, these regions bear cloud cover, but present unknown ceiling height and/or visibility. Thus, low ceiling and/or visibility could be present. We are exploring the informative value of confidence metrics and display options to represent the occurrence of indeterminate conditions.

4. FORECAST PRODUCT COMPONENTS

The NCV plan makes use of several forecast components and techniques, and we are only at the beginning of that implementation. The key elements of the conceived forecast system are illustrated schematically in Fig. 2, which also shows the fuzzy logic-based system currently in place to weight and merge forecast information through an additive model.

Overall, the NCV strategy is anchored by the use of the RUC40 (40-km horizontal grid resolution over the CONUS) and, when introduced operationally in early 2002, the RUC20 bearing a variety of improvements referenced below. Beyond this anchor, we prepare for use of several complementary forecast techniques and resources that should bring additional forecast skill in focused areas. We briefly outline these components below.

RUC20: As described in this volume by Benjamin *et al.* (2002) and Smith *et al.* (2002), the RUC20 incorporates a variety of improvements (in resolution, model physics, data assimilation, and visibility processing) that will further refine skill related to aviation impact variables. Its rapid cycling further defines it as the operational model of choice for the NCV product system. Each hour, the NCV system accepts updated 1, 3 and 6 h RUC forecast grids. In the future we expect to extend forecasts through 9 and 12 hours. That effort will await advancement in our capability to diagnose overall performance of the NCV system.

While some of the improvements cited above were developed through FAA funding, that effort also explores improvements that may relate directly to the NCV program. As part of that work, developers at NOAA/FSL (for RUC20) and NRL (for COAMPS, the Coupled Ocean/Atmosphere Mesoscale Prediction System model) are examining two areas in particular where COAMPS capability may yield directions for future RUC development – model microphysics and aerosol effects. Initial results from this work will emerge over the next year.

COAMPS: Operational runs of the Navy COAMPS model (Hodur, 1997) are used in place of the RUC in the southern California exploratory product of particular interest to the Navy.

Persistence: In its present static form, the persistence forecast component simply carries forward current C&V conditions for each point observation site. While reasonably effective for short forecast periods, persistence of course loses skill at longer periods (3-6 h) and in rapidly changing situations. Future refinement to the persistence forecast will take tendencies (trends) into account to extrapolate to the forecast time.

COBEL Column Model: Phenomena such as fog and low stratus are closely coupled to the influence of the surface on the atmosphere, and strongly impact C&V conditions. Thus, it is highly beneficial to the forecast process to explicitly represent the radiative, microphysical and turbulent processes at work in the boundary layer (BL) with the high vertical resolution needed to capture events such as these. The COBEL 1-D column model (Guedalia and Bergot, 1994) comprises the detailed BL component of the NCV forecast system, and its integration as a real-time resource for use in selected locations is in progress. First application of COBEL for NCV use will target the NY/NJ area and the frequent fog and low cloud events there. The model is also in use as a key element of AWRP's Terminal C&V effort toward forecasting stratus cloud impacts at San Francisco Intl. Airport.

To incorporate the influence of mesoscale forcing, COBEL implementation interfaces to RUC-derived output quantifying advection. Development effort underway to accommodate winter time use includes im-

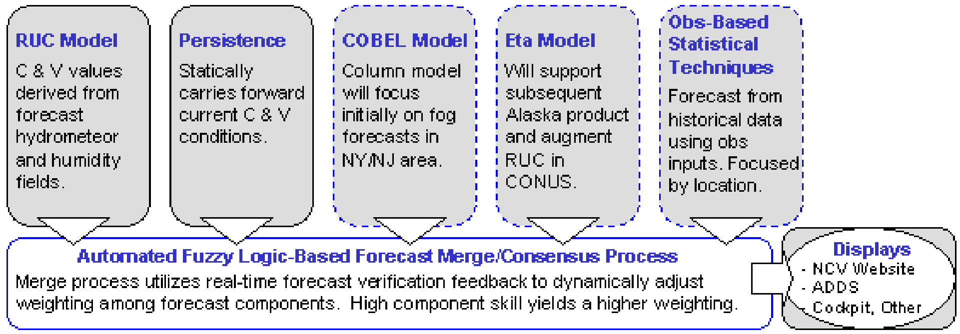

Figure 3. *Schematic representation of NCV forecast system components (top) for CONUS C&V in use today (solid outlines) and those planned for future use (dashed outlines). Forecast components flow (downward) to the automated merging process shown at bottom.*

plementation of the explicit mixed-phase microphysics method of Reisner et al. (1998) and corresponding addition of ice-phase radiation effects in the model. More information about COBEL is available from the University of Quebec at Montreal COBEL home page[2].

Observations-Based Forecasts: Probabilistic techniques offer means for rapidly-updateable automated forecasts of specific conditions (*e.g.*, low ceiling and visibility) at a specific location. The techniques use the long-term record of occurrence of the targeted condition and associated events at and near that location. Probabilistic approaches are expected to play an important role in short-term (~ 1-6 h) NCV forecasts, though the path to that role is not fully defined. Work to evaluate and apply techniques developed by the Terminal C&V program (Clark, 2002, this volume) is under way. We also examine the techniques described elsewhere (*e.g.*, Hilliker and Fritsch,1999; and others) and explore possible alternative methods.

5. FIELD STUDIES IN THE NE CORRIDOR

Understanding of the basic phenomenology driving adverse C&V conditions is a key factor underlying the success of this work. We have a particularly acute need for improved understanding of the processes responsible for the formation, evolution and dissipation of fog, precipitation and low cloud. To this end, the NE Corridor Field Program is now taking shape through partnership with the AWRP Winter Weather and Terminal Ceiling and Visibility programs. The study will utilize a broad array of surface, sounding, radiation and microphysical measurement systems at and around the Rutgers University New Jersey field site. The data obtained over a period of several years will be used to examine the occurrence and controls affecting fog, precipitation and low cloud and their impacts on C&V. Further information on this emerging program is being posted on the field study web site[3] on a continuing basis.

6. SUMMARY

This paper outlines the plans and first-year results of a long-term R&D program directed toward improved automated analysis and forecast tools for avoidance of in-flight C&V hazards. We principally target general aviation needs for C&V information, where improved access and utilization of briefing and in-flight guidance information can lead to a significant improvement in the safety record.

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