Advanced Weather Technology

Tuesday, October 16, 2018, 1:00 PM – 2:00 PM

PRESENTED BY: Gary Pokodner, FAA WTIC Program Manager

Agenda

- Overview
- Augmented reality mobile application
- Crowd Sourcing
  - Visibility and ceiling information
  - Wind Information
  - Crowd sourcing “photo PIREPs”
  - “MET visibility” versus “Aviation visibility”
- PIREPS
- Nulling out NEXRAD latency
- Graphical Turbulence Guidance Nowcast (GTGN)

Overview

- FAA Weather Research Programs
  - Weather Technology in the Cockpit (WTIC)
  - Aviation Weather Research Program (AWRP)
- Course objectives
  - Outreach Wx enhancements being developed to resolve gaps and associated operational shortfalls
  - Solicit feedback from users on research presented and high priority gaps and shortfalls

AUGMENTED REALITY

Augmented Reality Mobile Application

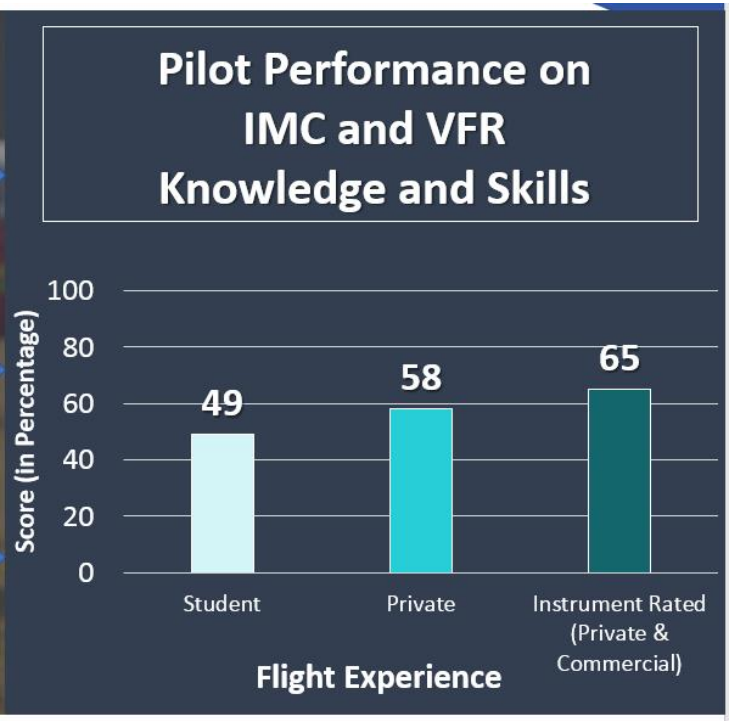
- Application developed to enhance training and address Wx knowledge gaps
  - WTIC study by ERAU identified pilot lack of weather knowledge
  - Application intended to serve as handy Wx resource and training tool
  - Potential for experiential training with use of 3D

Pilot Wx Knowledge Scores

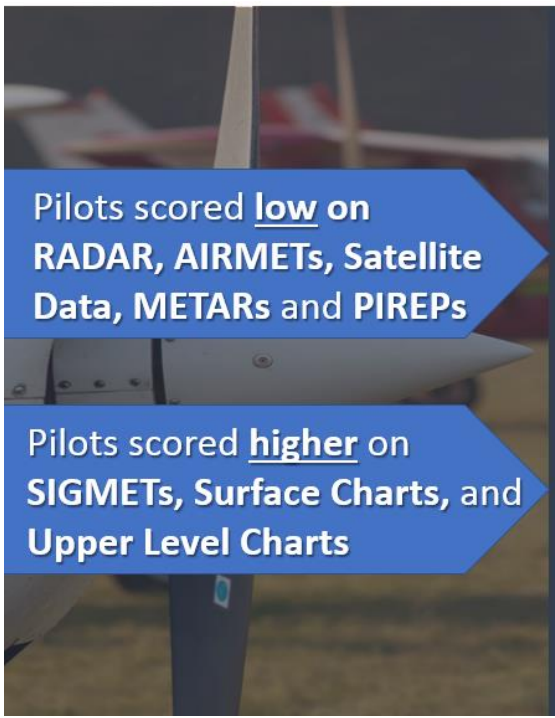
Overall, pilots' scores were **low** on interpreting **IMC weather information.**

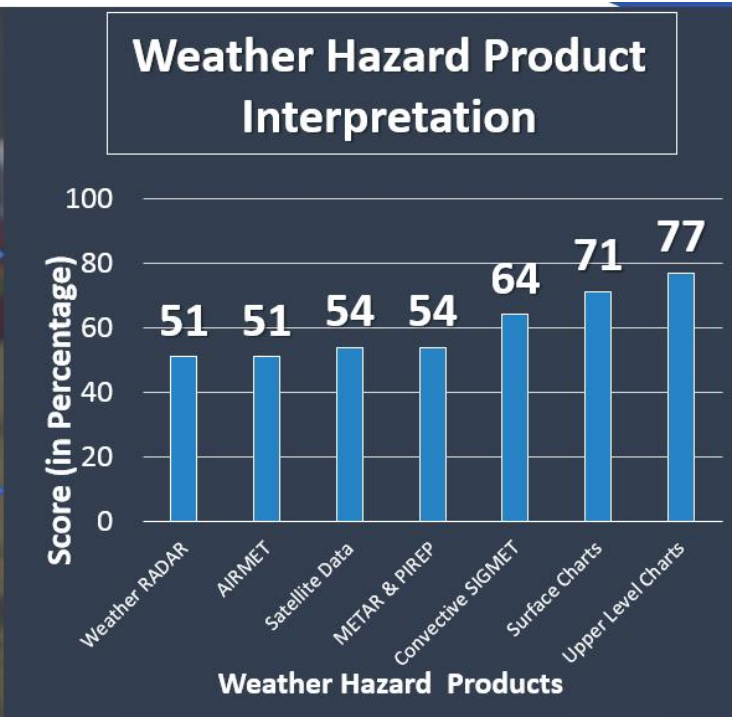
This includes **Surface Charts, Satellite Data, & PIREPs** involving **IMC weather**

Instrument-rated pilots scored the **highest**.



Pilot Wx Knowledge Scores



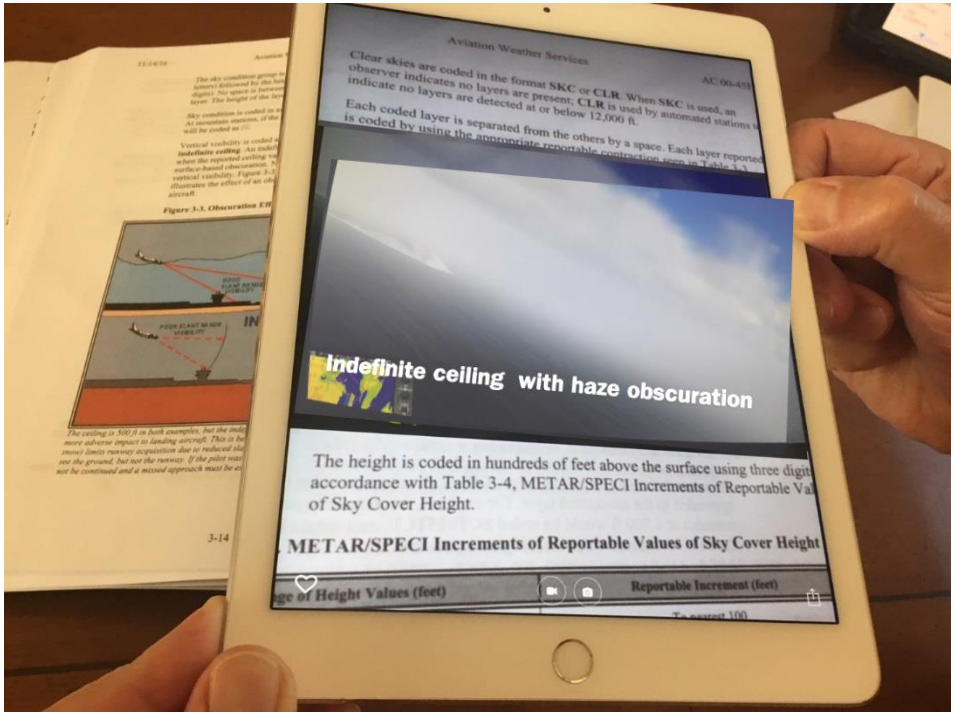


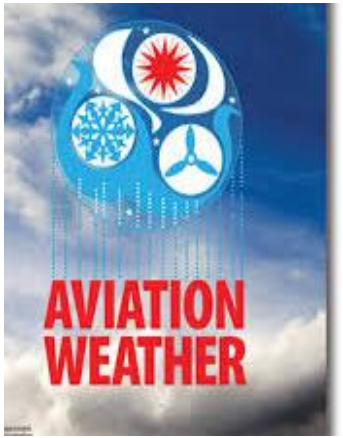
Augmented Reality Mobile Application

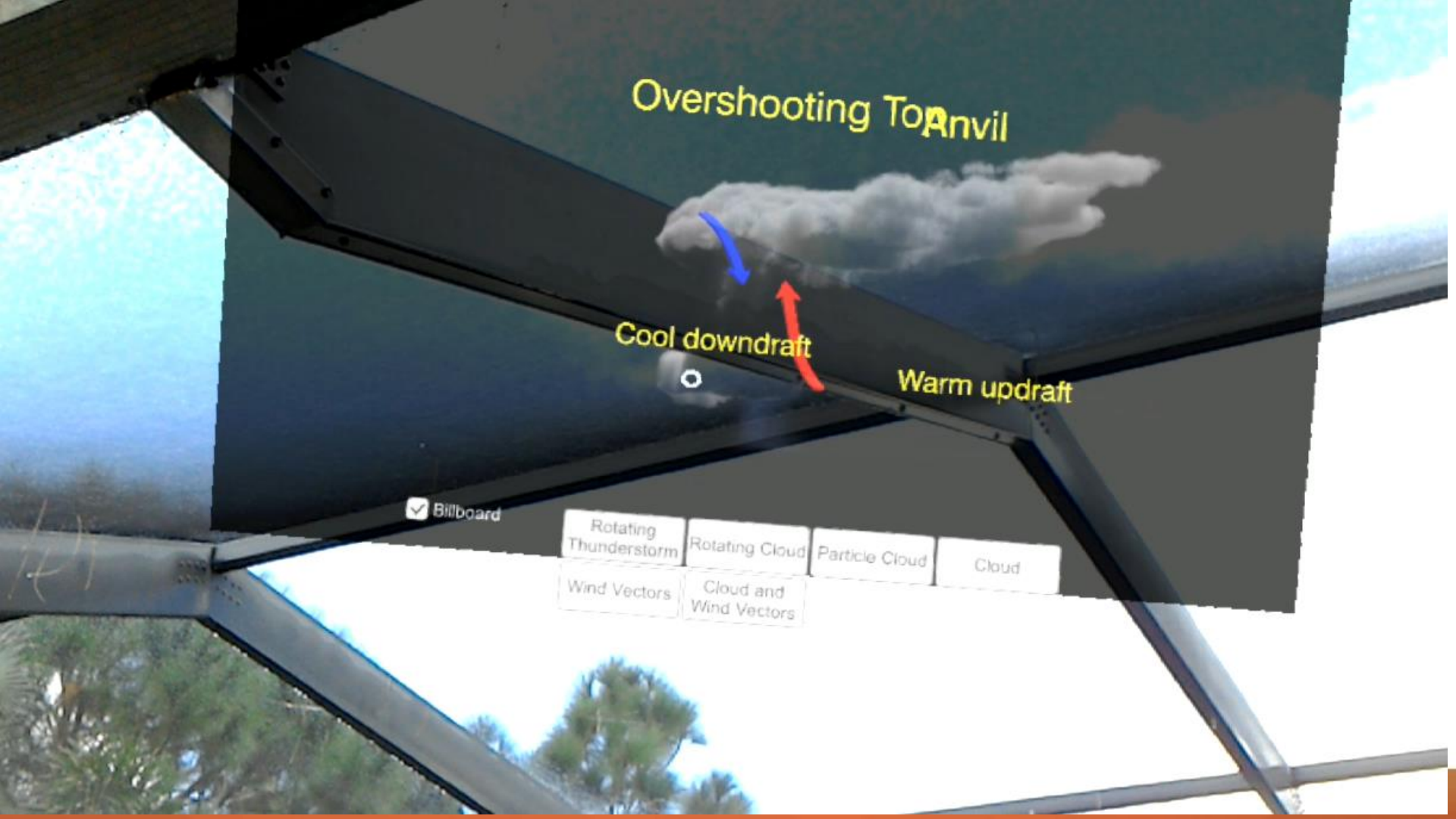
Augmented Reality - Printed Images Become Interactive

- Link images from advisory circulars, handbooks or notes to the respective URL such as interactive PIREPS
- Images can be used from the Advisory Circulars or download the “What can I scan booklet” at:
- https://mobileapps.tietronix.com/WeatherXplore/.

Augmented Reality - Example






Overshooting Top
Anvil
Cool downdraft
Warm updraft
Billboard
Rotating Thunderstorm
Rotating Cloud
Particle Cloud
Cloud
Wind Vectors
Cloud and Wind Vectors

Augmented Reality

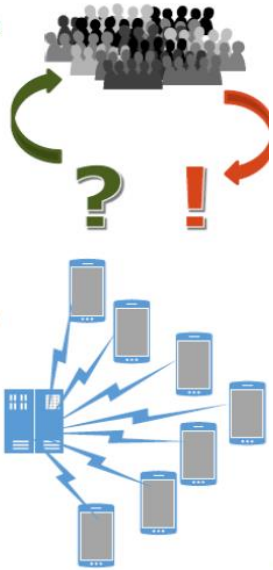
- Download app: **WeatherXplore** at Apple Store or Google Play
- Prototype has Survey tab to provide feedback

CROWD SOURCING

Crowd Sourcing

What is Crowd Sourcing

- The term is used for 2 broad concepts
  1. Crowd as Processor: Enlisting the contributions of a large number of networked participants in solving problems for which human intelligence performs better than automation
     a) **Volunteers** with an interest in the problem being solved
     b) **Inadvertent "Volunteers"** who perform the desired task for their own purposes (e.g., the "CAPTCHA's" used on web sites to verify that they are being accessed by humans)
     c) **Persons paid** a small amount per decision to perform the task (e.g., the Amazon Mechanical Turk web service)
  2. Crowd as Sensor: Gathering anonymous data from a large number of networked platforms for automated mathematical or statistical analysis (e.g., inferring city traffic congestion from cell phone tracking data)



Crowd Sourcing – Visibility Information

- Goals
  - Determine whether Crowd Sourcing weather information using cameras produces useful visibility information
  - Prototype Crowd Source architecture for visibility information using Alaska Webcams
  - Evaluate outputs of crowd sourcing for pilot utility
    - Investigate potential for use as model observation inputs
    - Compare utility of crowd source output to Webcam images

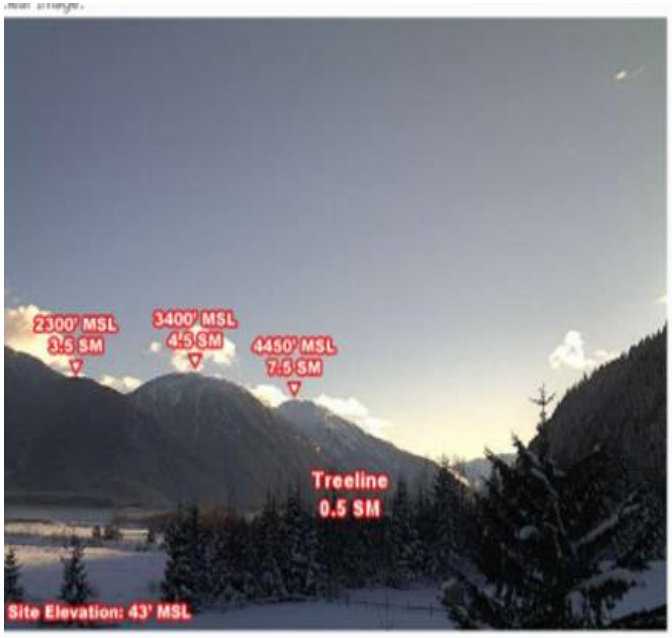
Crowd Sourcing – Visibility Information

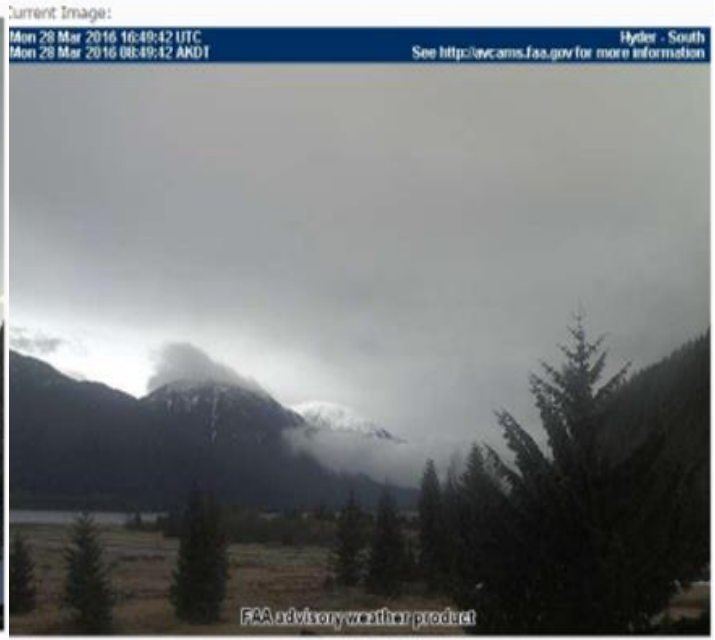
- Prototype Architecture
  - Used Amazon Mechanical Turk
    - Commercial crowd sourcing infrastructure, pay as you go
    - Provides 24/7 access to worldwide “crowd” of “workers”
  - Expectation Maximum (EM) algorithm to converge to solution
    - Rate workers based on past performance (better workers lead to quicker convergence, weed out poor workers)
  - Minimal training for workers
  - Use Alaska webcams and third party camera
  - Use Google Earth to add reference markers

Human Intelligence Task- Example

Instructions

For the images below, use the clear air image as a reference and estimate the ground visibility (in Statute Miles) in the current image. If the image is entirely obscured, set a value of 0.0. If the visibility exceeds the scale, just set the maximum value of the scale.





Crowd Sourcing – Visibility Information

- Summary of Findings
  - 81.4% of the visibility results were within 20% of the ASOS visibility
  - 16.5% were between 20% and 50%
  - 2% were more than 50% from ASOS visibility
  - ASOS results may not always provide maximum utility to pilots in “challenging” visibility conditions
    - Pilot assessments of visibility conditions varied greatly
  - Some cameras are not good choices for crowd sourcing

Crowd Sourcing – Visibility Information

- Summary of Findings
  - Pilots found Crowd-Sourced outputs easier to evaluate than images and the FAA Camera looping for trends
  - Pilots trusted Crowd-Sourced results compared to their own assessments
  - Decision times on visibility significantly reduced
  - Mechanical Turk provided large pool of workers, but participants varied so difficult to keep rated workers
  - Hybrid system using machine learning and edge detection may provide best value and solutions

Crowd Sourcing – Visibility Information

Next Phase

- Recently completed successful demonstration of hybrid solution using edge detection software and crowd sourcing
  - Edge detection used to measure visibility in certain conditions, monitors for changing conditions, and controls switch for sending images to the crowd to process when needed
  - Hybrid solution significantly reduced the amount of crowd sourcing needed
  - Looking at ways to get “volunteer” crowds to further lower costs
  - “Selective crowd” likely to result in faster convergence and high confidence
  - Adding additional logic to maximize quality and efficiency, and minimize costs

Crowd Sourcing – Ceiling Information

- Successfully demonstrated a similar process to crowd sourcing visibility to produce ceiling information
- Modifying techniques to enhance performance and to perform a demo

Crowd Sourcing – Wind Information

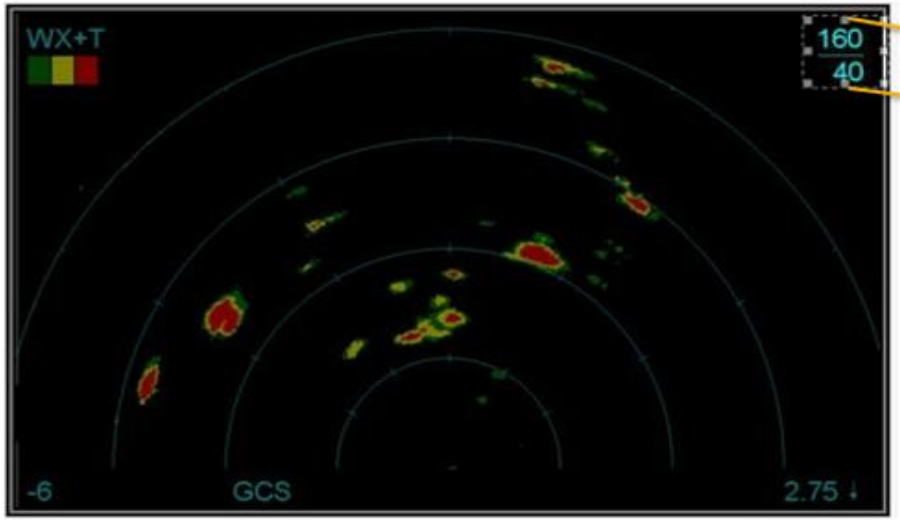
- Research employing convolutional neural network (CNN) machine learning techniques to determine answers to the questions:
  - What are the key challenges involved in automating the determination of surface wind speed and direction over runways at uncontrolled airports using a single web camera?
  - What are the requirements on the configuration/placement of the web camera in relation to the wind sock to obtain the highest quality information?
  - What is the expected reproducibility of the results?

Crowd Sourcing – Wind Information

- Successful feasibility study using Harris Helios product and analytics to calculate wind speed and direction via a camera pointed at a wind sock
- Study identified camera position and performance for optimum results
- Analytics also detected issues with windsocks
- Additional imagery and training of analytics would improve results
- Applications and additional research under review

Crowd Sourcing – “Photo PIREPs”

Forward Looking Radar – Optical Character Recognition



Source WxR Image Graphic

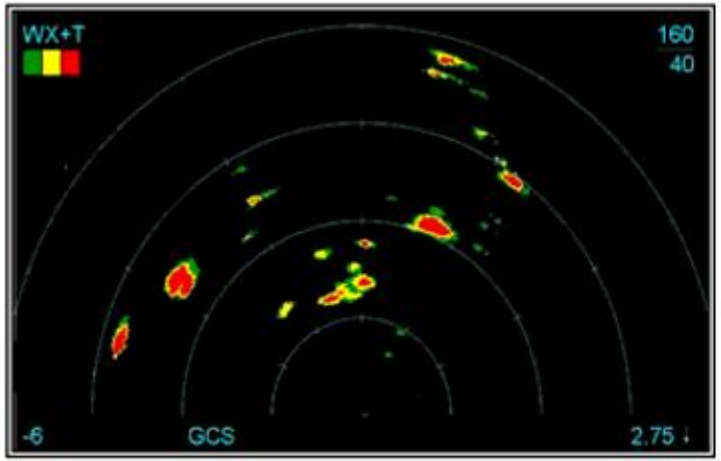
http://www.newocr.com/

160
40

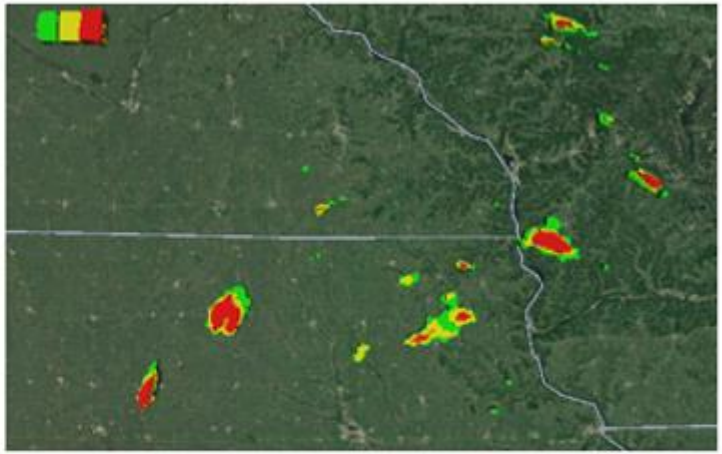
FreeWare OCR software extracting Range and Range Ring Distance Information from Source Image

Crowd Sourcing – “Photo PIREPs”

Forward Looking Radar – Object Classification



Source WxR Image Graphic



Weather Cells Segmented and Georeferenced (Displayed in Google Earth)

“MET Visibility” versus “Aviation Visibility”

ASOS = 4 mi

CrS = 3.8 mi

“MET Visibility” versus “Aviation Visibility”

ASOS = 9 mi

CrS = 2.0 mi

NOTE: MAX ASOS visibility is 10 miles

“MET Visibility” versus “Aviation Visibility”

ASOS = 1 mi

CrS = 1.0 mi

“MET Visibility” versus “Aviation Visibility”

ASOS = 8 mi

CrS = 2.0 mi

“MET Visibility” versus “Aviation Visibility”

Can crowd sourcing provide more utility than “MET Visibility?”

ASOS = 8 mi

CrS = 2.0 mi

Mtn obs at 6 Mi, 15 mi

PIREPS

Why Are PIREPs Important

A PIREP is the most direct way to help another pilot

- Pilots use PIREPs during pre-flight planning and during flight to get first-hand direct observations of weather
- Forecasters use PIREPs in developing and updating weather forecasts
- Pilots, dispatchers and ATC need PIREPs for strategic and tactical planning

https://aircrafticing.grc.nasa.gov/1_1_5_11.html https://www.ntsb.gov/safety/safety-alerts/Documents/SA_064.pdf

PIREPs

What types are useful?

- Timely and accurate reports
- Late-reported PIREPs if time and location are reported accurately
- Null and light conditions, as well as conditions “as forecasted” are important reports
- Those requested through Air Traffic Control (ATC) or Flight Service Stations (FSS)

PIREPs

Barriers to submitting PIREPs

- Unaware that all weather conditions are important – as forecasted or not as forecasted
- Lack of confidence in ability to accurately assess weather conditions
- Lack of consistent guidance and criteria for WX reporting
- Low proficiency or comfort level with PIREP submission levels
- Belief that their PIREP will not be disseminated to others

Study to Enhance PIREP Submittals

Looking for features to increase submittals

- Research Question: Which features on a PIREP submission tool do pilots believe will make them more likely to submit PIREPs?

PIREPs - Screens Demo

- Open Demo File
- WTIC NBAA Screens Demo Slides.pptx

NULLING NEXRAD LATENCY

Nulling NEXRAD Latency

Latency vs forecast error in NEXRAD display?

- Evaluated and selected method for radar nowcasting
- Selected methodology to support pilot study
- Implemented and evaluated forecast methodology

Nulling NEXRAD Latency

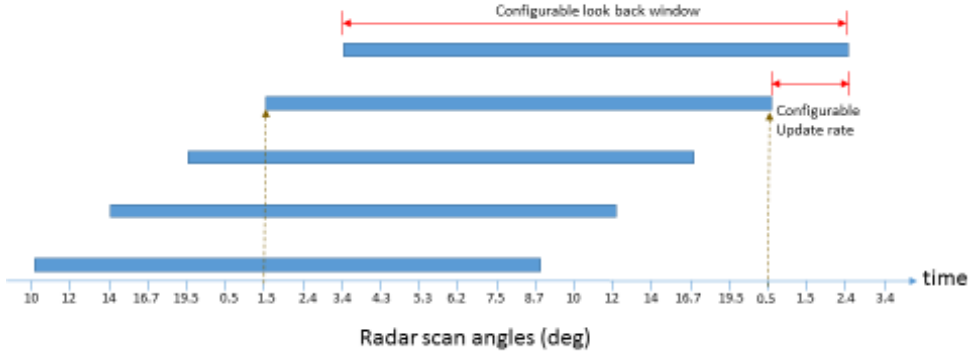
Virtual Volume Selector configuration

A typical convective weather scanning strategy for NEXRADS

- A volume starts at 0.5 deg and ends at 19.5 deg
- Data is sent by scan angle but most systems wait for a full volume before processing
- Full volume scanning will take approximately 5-6 minutes to complete

Virtual Volume processing:

- Set configurable look back window to 6 minutes
- Set configurable update rate to 1 minute
  - Triggers on next scan to arrive after 1 minute
- Composite all scans that fall within the look back window
- If a scan is found more than once then only use latest



Used modified processing technique to reduce latency may be applicable for operations

Nulling NEXRAD Latency

Methodology to Extrapolate Storms with/without Growth and Decay

- 5 cases selected for initial evaluation
  - Presented at 26 April 2018 PMR
- Three methods of analysis used:
  - Nowcasts without growth and decay applied
  - Nowcasts with growth and decay applied
  - Persistence
- Data sets used:
  - Virtual volumes created at ~1 min intervals
  - MRMS composite reflectivity at ~2 min intervals

7 additional cases selected for evaluation

- Same methods and data sets as above, except no MRMS

7 August 2018 FAA WTIC PMR 9

Various algorithms evaluated to do nowcasting

Nulling NEXRAD Latency

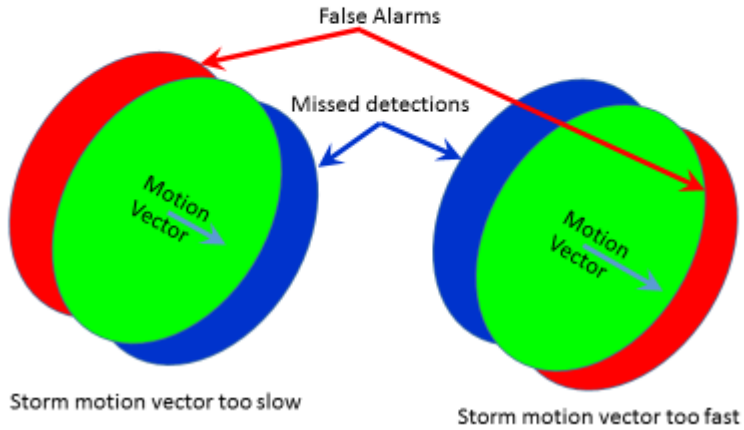
Summary of cases

- 12 cases examined
  - Detailed descriptions at end of talk
- Included squall lines, large storms, popcorn convection, mixed
- Examined CSI and Bias scores of each case for:
  - Storm extrapolation using Virtual Volumes
  - Storm extrapolation using Virtual Volumes with growth and decay
  - Persistence
  - MRMS storm extrapolation results without growth and decay for 5 cases
- Findings:
  - Persistence performed well for 1-2 min
  - Little difference between storm extrapolation with/without growth and decay
  - MRMS extrapolation results mixed performance compared to Virtual Volume but generally not quite as good
  - Good storm motion vector is key to getting high quality nowcasts
  - No one storm extrapolation technique is the best in all situations or for all nowcast lead times
    - Can depend on the type of storms occurring

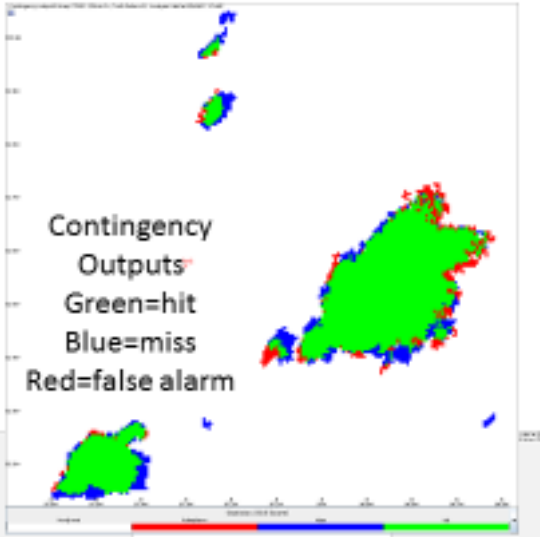
Nulling NEXRAD Latency

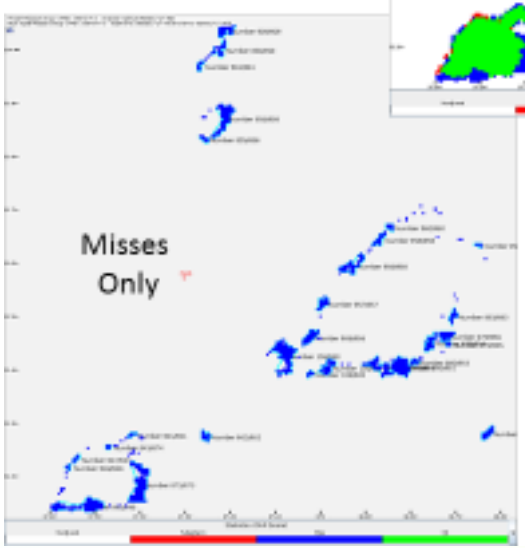
Contingency Table Plots

- Green=hits; blue=misses; red=false alarms
- For error analysis, storm extrapolation is done without growth and decay
  - Storm shape is advected forward in time

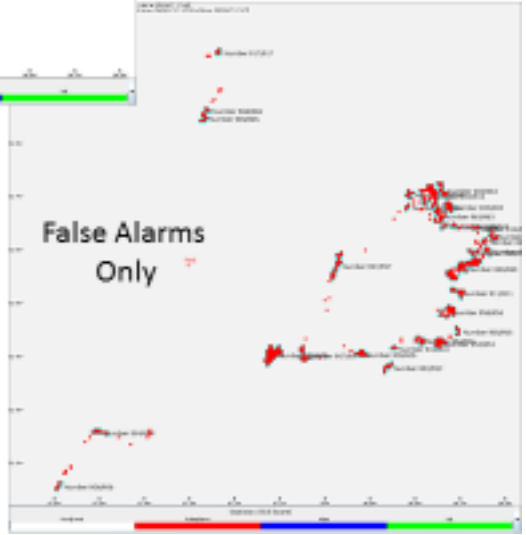


Example shows Thresholding of Contingency Mdv Files





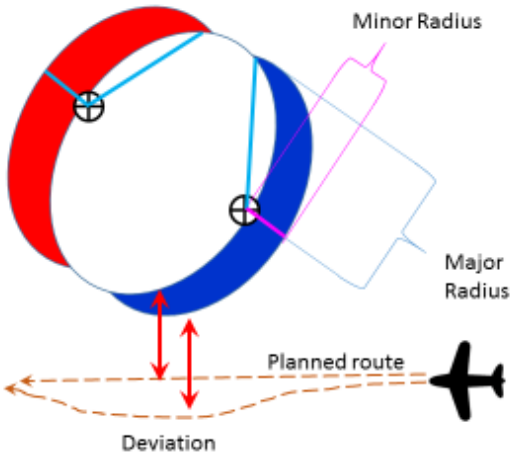
TITAN polygons shown in cyan, labeled with storm track numbers



Nulling NEXRAD Latency

Minor vs Major Radius

- Major radius measures distance from centroid to farthest edge of the storm
- Minor radius measures distance between centroid and edge of the storm
  - Used as measure of forecast error
  - Distance that will be "experienced" by pilots as they do strategic course correction



Nulling NEXRAD Latency

Comparison of Mean Radius Length by Storm Type for 15 min Nowcast

Fx 15min	Large Individual Storms, 5 cases		Popcorn, 3 cases		Squall Line, 3 cases	
	Misses	False Alarms	Misses	False Alarms	Misses	False Alarms
Mean major radius (km)	3.09	2.83	2.72	2.57	3.04	2.96
Mean minor radius (km)	1.35	1.29	1.21	1.14	1.30	1.29
Mean area (km^2)	23.59	19.92	15.53	12.39	27.91	27.18
Mean aspect ratio	2.55	2.54	2.55	2.56	2.45	2.46

Mean (M+FA) Minor Radius Length

Large Individual storms: 1.32 km

Squall line: 1.30 km

Popcorn convection: 1.18 km

All Storms: 1.26 km

Summary of Verification Results

- Analysis of misses and false alarms areas used to give estimate of forecast location error
- Minor radius provides good estimate of location error
- Some differences in location error when storm type is considered
  - Large storms can have larger error than popcorn convection
  - Expect that storms with higher motion velocity could have a greater error, but not examined

Nulling NEXRAD Latency

Disclaimer goals:

- These are forecasts
- Intensity is constant
- There are errors in location
- Threshold reflectivity used to measure errors is >=35 dBZ
- Position errors increase linearly over time out to 15min
- Error usually varies from 0.65NM at 1 min to 1.35NM at 15 min
- Large storms have greater position error than small storms **
- Faster storms have greater position error than slower storms

Nulling NEXRAD Latency

Proposed text:

"Data shows the forecasted location of storms, assuming no change in intensity.
Expected errors in the position of the 35dBZ contour increase from 1NM to 1.5NM over 15min."

Nulling NEXRAD Latency

Pilot Evaluation

- Test whether there is a benefit to presenting:

A "nulled" radar forecast, valid at the current time (with some caution about forecasting errors)
vs
A latent radar observation, valid several minutes ago (with the pilot's error in imperfect human forecast)

- Questions to answer:
  1. Do pilots have a **better** understanding of the current conditions? as measured by:
     - How closely their awareness matches reality in space, time, and/or intensity
     - How easily or quickly they arrive at a decision
     - How well they maintain separation from the hazard
  2. **Why** do pilots have the perception that they do?
     - Is it related to their confidence in either presentation source?
     - Does confidence result in improved or reduced safety?
  3. Does either presentation contribute to better **strategic** decision-making? as measured by:
     - Improved anticipation of future conditions?
     - Earlier decision-making?
     - Increased margin of safety around hazards?
     - Increased confidence in decisions?

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GRAPHICAL TURBULENCE GUIDANCE NOWCAST (GTGN)

Graphical Turbulence Guidance “Nowcast” (GTGN)

- Designed for use as a tactical turbulence avoidance product
  - Rapid update cycle of 15 minutes, valid for next 15 minutes
- Observation-centric:
  - Nudges GTG to better agree with most recent turbulence obs
  - Uses both airborne (PIREPS, in situ EDR) and ground-based radar observations (NEXRAD Turbulence Detection Algorithm-NTDA)
- Outputs all sources of turbulence (low level, mountain wave, CAT, in-cloud) in a 3D map of EDR, same grid as GTG

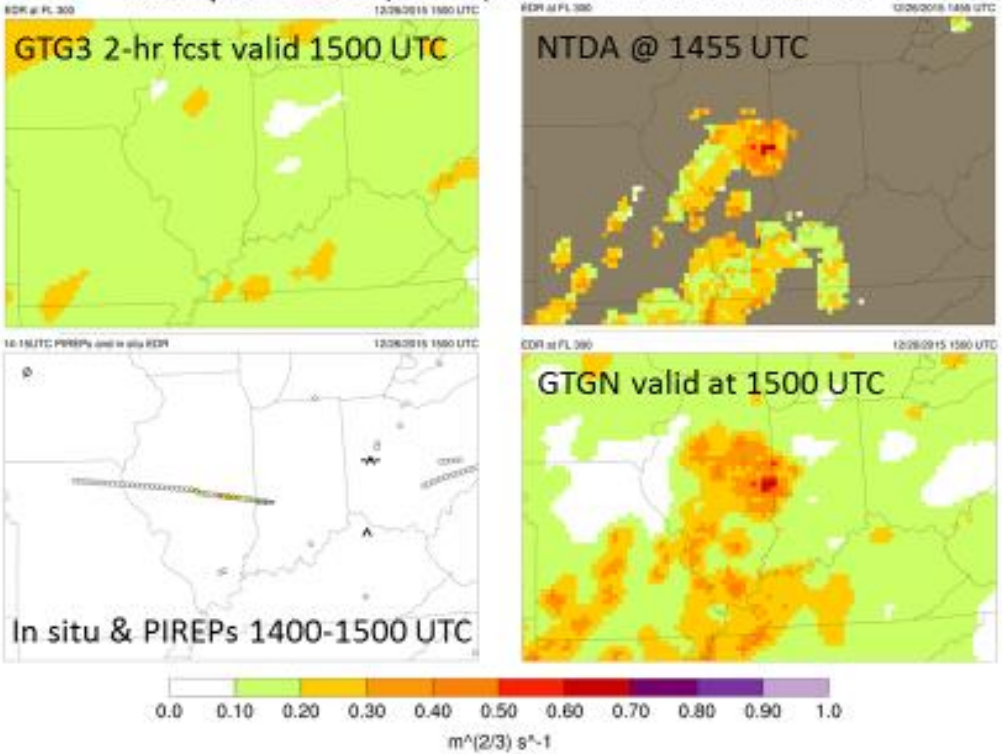
GTGN Operational Evaluation

Project Goals

- Evaluate and refine the product display
- Evaluate how the product is used by the crews
- Determine the GTGN product's strengths and weaknesses
- Provide input to the FAA's Safety Risk Management Approval Process
    - Feed back from crews
    - Identify shortfalls in capabilities and mitigation steps
    - Identify potential enhancements to usability

GTG-Nowcast

Example: Dec 26, 2015, valid at 1500UTC FL300



Delta Air Lines Weather Viewer App

Crews are provided "threat" information rather than met graphics such as fronts, etc

Alert box identifies the highest value within the alert area

Pre-programmed route of flight

The Vertical Profile provides a cross-section of potential turbulence threats along flight path.

GTGN Operational Evaluation

Benefits identified to date

- More timely cockpit decisions due to real time access to data
- Reduction in pilot-controller workload from reduced communications
- Reduction in number of unnecessary pilot-initiated altitude deviations
- Reduction in excess fuel consumption and greenhouse gas emissions due to more aircraft operating at optimal flight altitudes
- Reduction in reallocated (“blocked”) airspace

Questions and Discussion

- Contact Information
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