



NWS Science and Technology Roadmap

Verification and Performance Management Team



Team Composition



- **David Ruth, NWS/OST/MDL/MPB—Team Co-Leader**
- **Jamie Vavra, NWS/OST/PPD/SPB —Team Co-Leader**
- **Douglas Young, NWS/OCWWS/RAD/PB—Contributor**
- **Brent MacAloney, NWS/OCWWS/RAD/PB—Contributor**
- **Wayne Presnell, NWS/OCWWS/RAD/PB—Contributor**
- **Geoff DiMego, NWS/EMC/MMB—Contributor**



Vision/Benefits/Impacts

- **Team Vision:**

- *Improved performance management and state-of-the-art verification capabilities that assess all NWS operational warnings, forecasts and advisories, encompassing short-term to climate scale, to measure the accuracy and reliability of information that will impact critical decisions and reduce loss of life and property.*

- **Benefits:**

- Forecaster feedback gained from verification data will assist in identification of value added by forecasters to numerical model and statistical guidance.
- Understand impact of weather and climate variability on verification skill scores.
- Understand forecast skill, quality, accuracy from a technical and operational perspective and the benefit and impact to customers.
- Improve customer understanding of NWS product skill, quality and accuracy.
- Improved real-time access to verification data enables improved Decision Support Services for high impact situations.
- Verify all official NWS products issued.

- **Impacts:**

- Objective results support decision-making for resource investment and allocation.
- Identify strengths and weaknesses of forecast process.
- Minimize uncertainty in the forecast.
- Improve performance through state of the art verification capabilities.
- Gains from verification can improve skill in all forecast areas; for example, tornado forecast improvements could reduce typical costs of over \$1 billion in property damage per year.
- Improved weather forecasts resulting from verification will reduce delays for air transportation, thereby reducing transportation costs by up to \$590 million per year.



Stretch Goal

Measure skill and impact of all NWS products, data and services using a suite of scientifically-sound performance analysis capabilities, with results that are integrated in a timely manner to ensure accurate and reliable environmental information for all missions during low to high impact events. Ensure forecast verification techniques are accurate, reliable and relevant.



Goals/Targets: Customer Needs

Expand Tools/Sources of Observations and Analyses, Statistical & Numerical Model Guidance

Goal	Outstanding Issues
Additional gridded analyses and observations to assess skill of NWS gridded forecasts.	Need verification sources for all gridded NDFD forecasts.
Verification data at a 2.5 km horizontal resolution for verification of CONUS NDFD gridded forecasts at 2.5 km horizontal resolution.	Need to increase verification source resolution to align with plans for forecast resolution increases.
Verification tools for evaluation of the forecast quality of weather features in gridded forecasts as related to the event timing and spatial distribution.	Grid to grid comparisons don't provide an effective measure of skill for forecast features that are highly discontinuous in space.
Understanding of verification and validation approaches and techniques and adoption of common standards NWS wide.	Each organization working on verification separately.



Goals/Targets: Customer Needs



Improve Verification of Human Generated Forecasts

Goal	Outstanding Issues
Improved understanding of forecast skill over all forecast time scales.	Need to understand skill out to climate scale forecast periods.
Capabilities for operationally based, high impact event verification for the event duration.	Verification today is primarily computed for monthly, seasonal and annual scores rather than for specific events.
Understand where forecasters add value to numerical model and statistical guidance.	Important to have objective evaluation of value added for resource decision-making.
Improved understanding of the value of the forecast verification.	Need to involve social scientists and targeted user groups in improving understanding of the value of forecast verification.
Forecasters, managers and decision-makers need feedback on forecast skill, accuracy, reliability and quality in real-time.	Forecasters need verification capabilities on AWIPS and verification results in real-time.



Goals/Targets: Customer Needs



Enhance Assessment of Customer Satisfaction

Goal	Outstanding Issues
Assess effectiveness of communication of uncertainty.	As we transition to communicate uncertainty more widely, we need to ensure we are communicating effectively so customers understand how to interpret that information.
Establish preapproved OMB web-based survey for real-time feedback on high-impact events that is open to all NWS management for real-time decision making. Establish metrics for baseline.	Need local capabilities to readily conduct surveys with customers and users using web-based tools at all NWS offices.
Assess warn on forecast performance skill and evaluate impact to customers.	As we transition to more widely use a warn on forecast approach, we need to ensure we are adding value by assessing forecast performance and ensuring that we do not adversely change hazard event false alarm rates.
Evaluation of customer satisfaction for critical NWS products and services.	Limited resources. \$40K required per professionally developed survey.



Goals/Targets: Customer Needs



Modernize Service Assessment

Goal	Outstanding Issues
Capabilities for rapid response to support local assessment of high impact weather events.	Need equipment at each NWS office, and national centers to support local assessments. Need equipment such as GPS, digital cameras, and servers for web-based archival of data for future use in national and regional assessments.
Understand effectiveness of decision assistance and support tools in increasing efficiency of forecast process at NWS offices.	As we transition to increased reliance on use of decision assistance tools, need to ensure forecast process at NWS offices is enhanced.
Capabilities to track storms by types. Desire improved damage estimates to support our partnership with FEMA in improving the understanding of the impact of high impact weather events.	Promote NOAA wide efforts to partner with FEMA, Army Corp of Engineers, Academic Sector, Private Sector to better meet their requirements.



Goals/Targets: Emerging Science & Technology



***Expand Tools and Sources of Observations, and Analyses, Statistical
& Numerical Model Guidance***

Goal/Target	Outstanding Issues
Enhance quality control techniques for observations used in analyses.	Need for exchange of quality statistics of observations. Resources are needed to develop more precise quality control methods appropriate for each observing system, e.g., dual-polar. radar.
Complete verification archive of data, verification tools, guidance and observations.	Funding to establish NCDC archival.
Access to improved Mesoscale datasets to improve representation of planetary boundary layer physics in analyses.	Need additional sources of observational data.
Improved downscaling methods and bias correction techniques for numerical models.	Needed for first guess on NDFD grid to enable the development of the North American Regional Reanalysis and 30 year climatology.
Verification techniques for probabilistic uncertainty forecasts.	Verification techniques for ensemble-based probabilities and uncertainty products are well known.



Goals/Targets: Emerging Science & Technology

Expand Tools and Sources of Observations, Analyses, Statistical & Numerical Model Guidance (continued)

Goal/Target	Outstanding Issues
Implement object oriented verification and regime based tools and methodologies agency wide to enhance evaluation of forecast skill. The purpose of this is to evaluate scenarios to see where forecasters have skill and where help is needed.	Use of object-oriented tools for verification not yet mature, or widely used or well understood. The NCAR Model Evaluation Tools capabilities are not synchronized with the object oriented tools in the Network-Enabled Verification Service (NEVS).
Additional sources of observational data to enhance representativeness of gridded analyses. Utilize data from sensors such as Water Vapor on aircraft.	Required to support transition to warn on forecast.
Enhance Analysis of Record RTMA for verification of Aviation Impact Variables by NextGen 2013 IOC: turbulence, ceiling height, obstructions to visibility, convection, and icing.	Observations for preparation of gridded analyses of some aviation impact variables are not available at a spatial density required. Some NCAR activities for analyzed/diagnosed products for Aviation variables; funding and resources to integrate these into the RTMA and AOR II are required.



Goals/Targets: Emerging Science & Technology

Expand Tools and Sources of Observations, Analyses, Statistical & Numerical Model Guidance (continued)

Goal/Target	Outstanding Issues
Assess quality of gridded forecasts and analyses using tools and techniques such as Forecast Convergence Score (FCS).	Need additional studies and techniques to assess forecast quality.
Analysis of Record (AOR) Phases II and III: •AOR Phase II will use a 4-dimensional data assimilation system with 3-D or 4-D Variational technique. •AOR Phase III will be a reanalysis of 30 years of observations for use as analysis climatology.	Need for high temporal and spatial reanalysis for a variety of weather and climate applications by agencies and customers.



Goals/Targets: Emerging Science & Technology



Improve Verification of Human Generated Forecasts

Goal/Target	Outstanding Issues
Extend Analysis of Record Phase I, Real-Time Mesoscale Analysis for all NDFD forecast elements operational today and planned by 2025.	Transition RTMA to 2.5 km horizontal resolution, add Delayed Mesoscale Analysis, add analyses for remaining NDFD variables, and extend gridded verification to 4 dimensions.
Proposed activities for RTMA Product Improvement Plan will address timeliness and quality aspects still needed.	Timeliness requirement – 30 minutes after hour. Quality requirement – Establish baseline and assess with cross-validation technique.
Implement NextGen Network-Enabled Verification Service (NEVS) and link with existing Stats on Demand System and other NWS Verification systems.	Implement for NextGen aviation impact variable verification by 2013. NEVS will provide capabilities needed for object oriented techniques for verification of Aviation products that could be applied to other NWS verification systems for other service area forecasts.
Enhanced data assimilation capabilities.	Needed to support transition to increased emphasis on warn on forecast. Needed to improve model first guess error. Data assimilation improvements are limited by available computing power. Need for additional emphasis on assimilation of radar observations.



Goals/Targets:

Emerging Science & Technology

Enhance Assessment of Customer Satisfaction

Goal/Target	Outstanding Issues
Develop IT tools and solutions for real-time assessment of customer satisfaction.	Need for scalable solutions for local and national use, and for standard tools and methodology for application nationally.
Work with social scientists to develop methodologies to assess efficiency gains from use of decision support tools at local offices and national centers.	Need to validate decision support tools use in forecast process at local offices and national centers.
Develop IT solutions and capabilities for rapid response surveys for real-time assessment of customers and partners following significant events.	Need involvement of social scientists to design effective tools.



Goals/Targets: Emerging Science & Technology



Modernize Service Assessment

Goal/Target	Outstanding Issues
Develop IT solutions and tools, and acquire equipment required at each NWS office and national centers to support rapid response and real-time local service assessments.	Need equipment such as GPS, digital cameras, and servers for web-based archival of data for future use in national, regional and local service assessments.
Work with social scientists to develop tools to assess effectiveness of uncertainty estimation and communication.	Required to support transition to warn on forecast.
Develop IT solutions and web-based tools and capability to archive large volume of data to support local, regional and national Service Assessments.	Real-time access to archives needed to support real-time decision making by NOAA and NWS senior level management.



Key Information Gaps

Expand Tools and Sources of Observations, Analyses, and Statistical & Numerical Model Guidance

Gap	Solution Alternative	Impact
<p>Gap #1</p> <ul style="list-style-type: none"> • Need high impact event verification tools and object-oriented verification tools. 	<p>1.1 Develop object-oriented techniques in the Network-Enabled Verification Service (NEVS) to assess quality of aviation impact weather variables.</p> <p>1.2 Develop web-based tools for assessment of individual storm type verification skill.</p>	<p>Improved capabilities for real-time feedback to forecasters and managers on forecast quality, impact and skill.</p>
<p>Gap #2</p> <ul style="list-style-type: none"> • Need customer based techniques for verification of probabilistic forecasts. • Need probabilistic ensemble data assimilation methodologies. 	<p>2.1 NextGen project for Network- Enabled Verification Service (NEVS) capabilities.</p> <p>2.2 Environmental Modeling Center Ensembles.</p> <p>2.3 Customer based probabilistic verification techniques.</p>	<p>Enables NWS to extend number and types of gridded deterministic and probabilistic forecasts verified to meet goals for NextGen IOC by 2013, and enhance impact of verification for specific customer groups.</p>



Key Information Gaps



Improve Verification of Human Generated Forecasts

Gap	Solution Alternative	Impact
<p>Gap #3</p> <ul style="list-style-type: none"> •Need gridded analyses for all NWS gridded forecasts in NDFD. •Need to improve representativeness of Analysis of Record Real-Time Mesoscale Analysis (RTMA). •Need to support planned horizontal resolution increase for OCONUS, and CONUS at 2.5 km. •Need gridded analyses for verification of NextGen IOC Aviation Weather Impact Variables planned by 2013: ceiling height, convection, turbulence, icing, and obstructions to visibility. 	<p>3.1.1 Interim solution: Analysis of Record (AOR) Phase 1: Expand Real-Time Mesoscale Analyses (RTMA), and develop Delayed Mesoscale Analysis (DMA).</p> <p>3.1.2 Long term solution: Analysis of Record (AOR) Phase II and III with improved 4-D Data Assimilation scheme for gridded verification at matching digital forecast resolution.</p> <p>3.1.3 Develop enhanced quality control methods for AOR.</p> <p>3.2 Global Analyses for gridded verification.</p> <p>3.3 Remotely sensed data for gridded verification.</p> <p>3.4 Increase density of observations for weather hazards in analyses, by using augmented mesonet data such as road weather information system observations.</p>	<ul style="list-style-type: none"> • Allows NWS capabilities to verify all gridded data made available via the NDFD, and met future plans to increase the horizontal resolution of the CONUS NDFD forecast data to 2.5 km resolution. • Allows NWS to use analyses for verification of new gridded NextGen IOC Aviation Weather Impact Variables required by 2013. • Allows NWS to prepare formal retrospective or delayed verification of NDFD and post IOC Aviation Weather Impact Variables at matching future digital forecast resolutions, and reanalysis data for climatological applications.



Key Information Gaps



Improve Verification of Human Generated Forecasts (continued)

Gap	Solution Alternative	Impact
<p>Gap #4</p> <ul style="list-style-type: none"> •Need to understand impact of climate variability on forecast skill scores. 	<p>4.1 Develop programs for evaluation of link between weather patterns and mean climate and verification skill scores. Conduct studies of seasonal mean climate anomalies and determine degree of correlation with variability in forecast skill scores for all NWS Service areas.</p> <p>4.2 Conduct manual studies using inspection of trends.</p>	<p>Improved understanding of variability in skill scores for all NWS Service areas, and improved capabilities for projecting realistic future improvements for key performance metrics.</p>
<p>Gap #5</p> <ul style="list-style-type: none"> •Need to understand where forecasters add value in gridded forecast process. 	<p>5.1 Conduct evaluations of gridded forecasts and guidance to identify geographic regions and forecast periods where forecasters improve upon available guidance.</p> <p>5.2 Conduct evaluations of gridded forecast skill based on stratification by event types to improve understanding of forecast skill for high impact storm event types.</p> <p>5.3 Implement NEVS capabilities for object oriented tools.</p>	<p>Improved understanding of NWS forecasters skill in providing highly accurate, reliable, and high quality forecasts.</p>



Key Information Gaps



Improve Verification of Human Generated Forecasts (continued)

Gap	Solution Alternative	Impact
<p>Gap #6</p> <ul style="list-style-type: none"> • Need to understand value of verification to NWS external customers and partners. 	<p>6.1 Conduct studies with social scientists and targeted user groups to assess value of verification provided for key customer defined thresholds.</p> <p>6.2 Develop NWS wide strategy for verification.</p> <p>6.3 Prepare inventory of all existing formal verification conducted by NWS and document unmet verification needs.</p>	<p>Improve support for verification budget requests in PPBES.</p>
<p>Gap #7.</p> <ul style="list-style-type: none"> • Need to provide forecasters gridded verification information in real-time. 	<p>7.1 Gridded Forecast Feedback System (GFFS), an OSIP project for a system of real-time verification feedback capabilities on AWIPS.</p> <p>7.2 Extend capabilities of Daily Forecast Critique, an existing tool on AWIPS.</p> <p>7.3 Include Boise Verify Smart Tool in AWIPS baseline.</p> <p>7.4 Implement and extend NEVS.</p>	<p>Forecasters able to use AWIPS and other web-based systems in real-time to understand how effective their forecast decision-making is for specific weather events and forecast regimes.</p>



Key Information Gaps



Enhance Assessment of Customer Satisfaction

Gap	Solution Alternative	Impact
<p>Gap #8.</p> <ul style="list-style-type: none"> • Need to promote understanding of NWS product skill, quality, reliability, and accuracy and also to understand key customer and partner requirements for verification. 	<p>8.1 Develop IT solutions to enhance public outreach capabilities for NWS product verification.</p> <p>8.2 Enhance and centralize NWS web pages for verification.</p> <p>8.3 Conduct virtual and in person verification workshops with key external partners and customers.</p> <p>8.4 Conduct Customer Satisfaction Surveys on uncertainty in the forecast at the national level as a part of experimental product prototyping.</p>	<ul style="list-style-type: none"> • Improved understanding and interpretation of NWS forecast verification information by public, users and partners. • Improve impact of verification.



Key Information Gaps



Modernize Service Assessment

Gap	Solution Alternative	Impact
<p>Gap #9.</p> <ul style="list-style-type: none"> •Need to assess the effectiveness of the communication of uncertainty in the forecasts from a customer and user perspective. 	<p>9.1 Conduct Focus Group Meetings with targeted customers to provide outreach and training on uncertainty in NWS products.</p> <p>9.2 Work with Social Scientists as a part of Service Assessments to evaluate how effectively customers interpret NWS products and their uncertainty.</p> <p>9.3 Evaluate the effectiveness of uncertainty information using objective verification techniques.</p>	<p>Improved understanding of how customers interpret NWS forecast products and their uncertainty.</p>
<p>Gap #10.</p> <ul style="list-style-type: none"> •Need real-time assessments of service for major events to better plan responses and shorten time to adjust practices as needed 	<p>10.1 Develop local tools and capacity needed for real-time Service Assessments.</p> <p>10.2 Develop IT solutions for centralized data access and a national archive of local Service Assessment data.</p>	<p>Able to shorten time to implement changes needed to resolve issues identified during Service Assessments.</p>



Research Needs and Opportunities



- **Short-term**

- Enhancements to Real-Time Mesoscale Analysis for Aviation variables, and development of Analysis of Record (AOR) Phase II with a 4-dimensional data assimilation technique.
- Provide capabilities for real-time local feedback on Gridded Forecasts in AWIPS.
- Enhance web-based capabilities for Public Outreach on Verification and NWS Skill.
- Develop Network-Enabled Verification Service for Aviation Services with object-oriented and regime based tools and methodologies.
- Investigate impact of weather regime/climate variability on verification skill scores.
- Work with targeted users to improve understanding of value of forecast verification.
- Develop methodologies to verify uncertainty forecasts and probabilistic analyses.
- Develop tools and local capacity for web-based surveys for individual office Customer Satisfaction Assessment



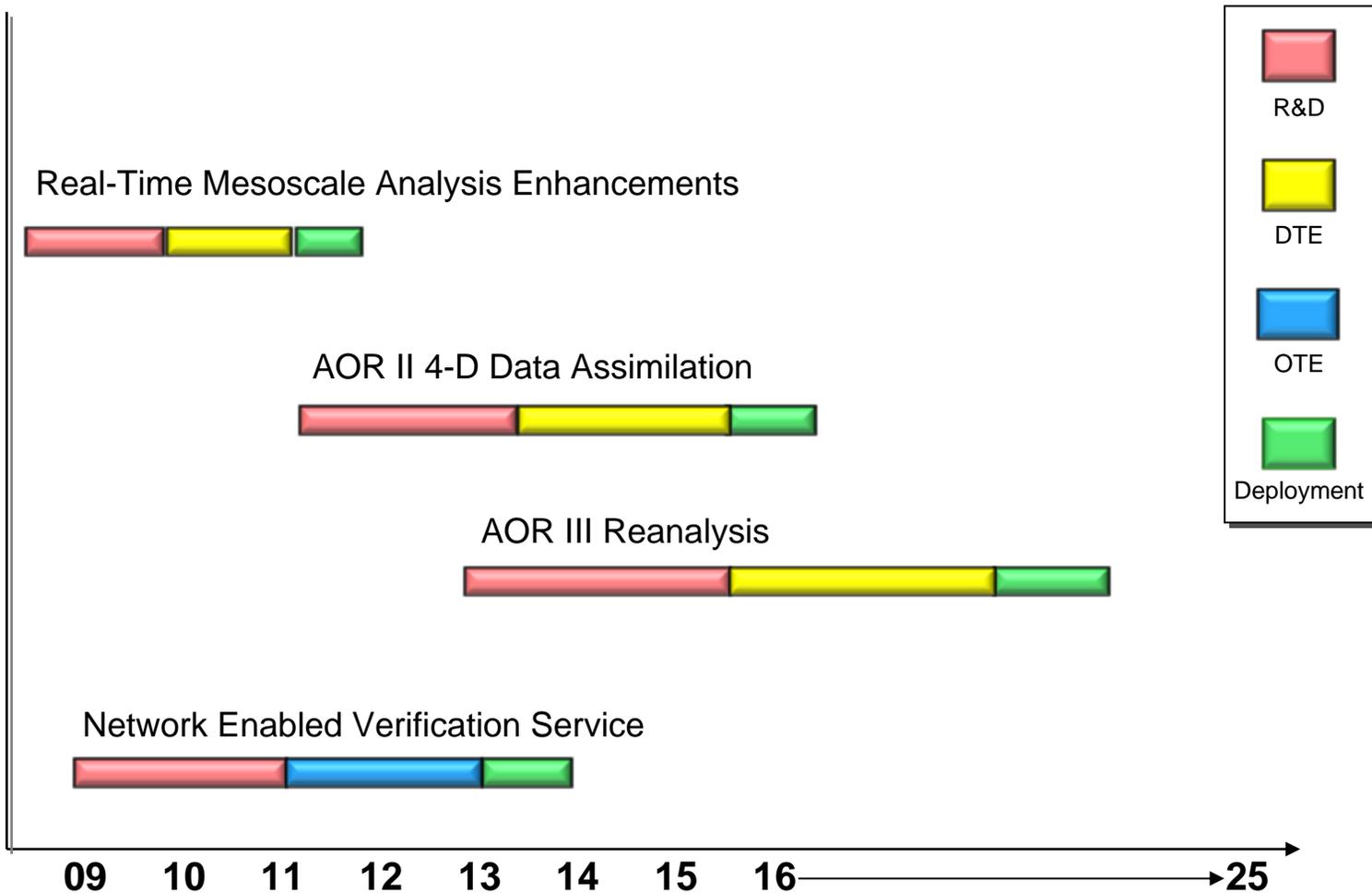
Research Needs and Opportunities



- **Long-term**
 - Research IT solutions for real-time rapid response service assessment of high-impact events.
 - Smart verification systems that identify where forecasters add value in real-time. Work with Social Scientists to develop methodologies for assessing customer satisfaction on NWS initiatives for forecast uncertainty and warn on forecast process.
 - NextGen verification – identify where add value in Aviation Forecast Process.
 - Work with Social Scientists and targeted customer groups to determine value of verification.
 - Refine AOR Phase II capabilities.
 - Develop AOR Phase III to produce a climatological re-analysis.
 - Implement object-oriented and regime based tools for verification of products in all Service Areas.
 - Develop methodologies for verification based upon customer impact for user defined thresholds.

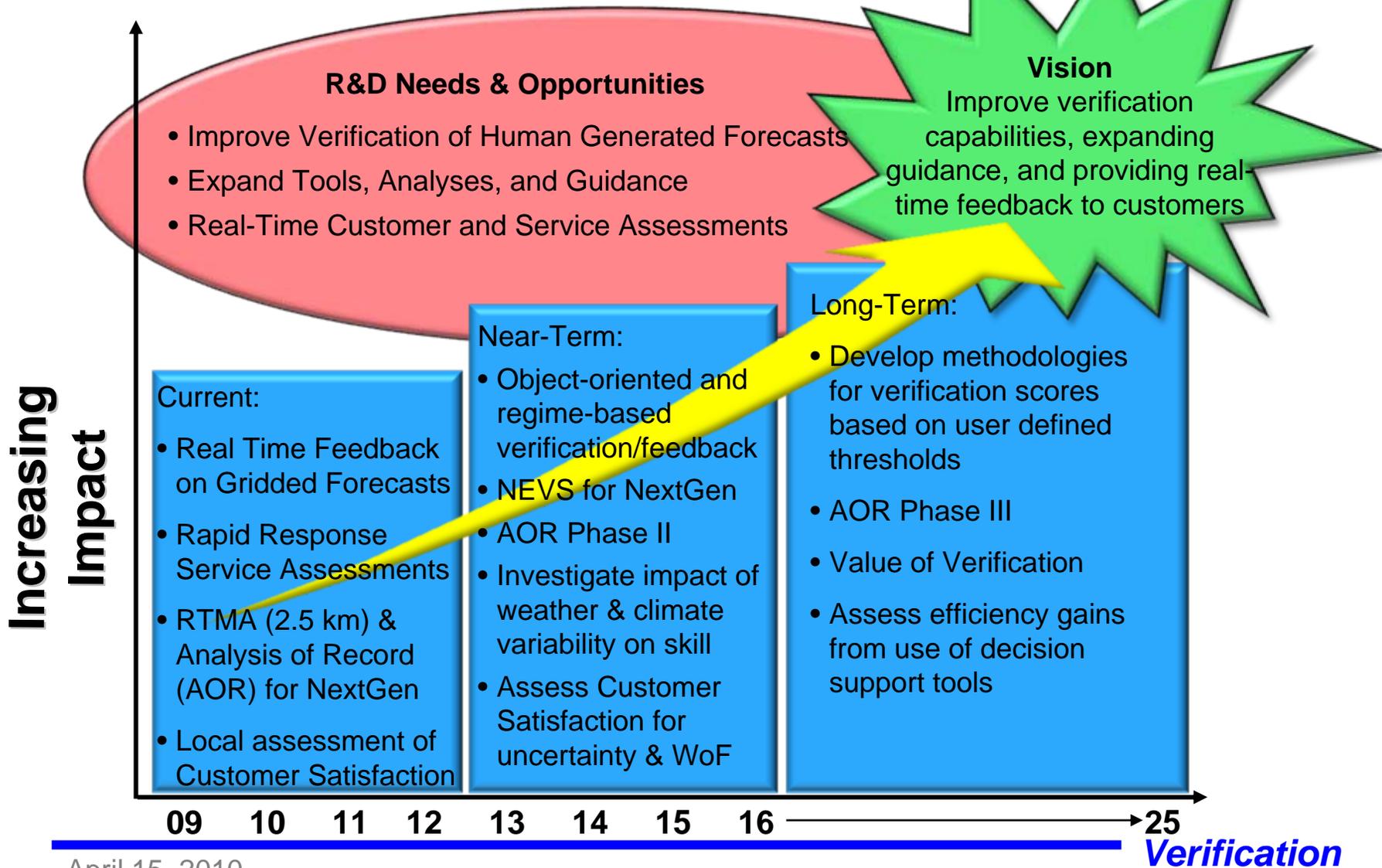


Verification Alternative Solutions





Focus Area Team Summary: Verification





NWS Science and Technology Roadmap

Verification and Performance Management Team Additional Information



Performance Measures: Verification



Proposed	Current (2009)	FY 2016 Target Example	FY 2025 Target Example
Enhance RTMA	Baseline		
AOR Phase I RTMA/DMA and enhancements	Establish Baseline 2010	Improve Baseline by 5%	Improve Baseline by 10%
AOR Phase II 4D-Data Assimilation		Establish Baseline	Improve by 5% per year
Network Enabled Verification Service (NEVS)	Baseline verification capabilities for NextGen IOC Aviation gridded products	Increase verification capabilities to include post NextGen IOC Aviation gridded products	Increase verification capabilities to include all NextGen FOC Aviation gridded products