NWS Science and Technology Roadmap

Severe Weather (SWX)

Team Composition

- **Dr. Daniel Meléndez, Co-lead, NWS/OST**
- **Dr. Russ Schneider, Co-lead, NWS/SPC**
- **Peter Browning, NWS/CR SSD**
- **Bernard Meissner, NWS/SR SSD**
- **Kevin Scharfenberg, OCWWS**

Operational Definitions

- **Warn-On-Forecast (WoF)-**
  - Capability to issue warnings of desired weather feature or event based on forecast data prior to the occurrence of the event rather than issuance based on detection ("warn-on-detection") of the feature or its immediate precursor.
  - Numerical weather prediction of individual storms
  - Assumes a certain level of skill has been achieved sufficient to have socioeconomic value similar or greater than warning on detection.

Vision/Benefits/Impacts

- **Team Vision**
  - ***High-resolution (neighborhood-scale) forecasting and warning of severe weather in close collaboration with agency partners to improve decision support services that reduce loss of life and property and provide economic advantages.***

- **Benefits**
  - Forecasters providing high-resolution (temporal and spatial) probabilistic severe weather data enabling specific decision support services
  - Warn-on-Forecast capability: much longer severe weather lead times without increased FAR
  - Significantly improved quantitative precipitation forecasts (flash flood)
  - Skillful tornado intensity prediction of strong tornadoes (EF3 and greater, 1300 times more injuries)
  - Decision support services communicating risk and uncertainty to decision makers
  - About **1,500 tornadoes** touch down across the United States yearly causing an **estimated $1.1 billion** in damages and over **80 deaths**
  - Tornadoes warned nearly doubled from 35% pre-NEXRAD to 60% post-NEXRAD
  - Between 1992 and 2004, NEXRAD prevented over **330 fatalities** and **7800 injuries** from tornadoes, resulting in over **$3 billion in savings**
    - Site acquisition and NEXRAD preparation costed less than **$1.7 billion** [2004 $s]

Vision/Benefits/Impacts

- **Benefits (continued)**
  - Average **warning lead time** increased from **5.3 to 9.5 minutes…large increases derived from improved radar and modeling**
  - National 1986-2004 reduction in False Alarm Rate (FAR) decreased fatalities 4%-11% and decreased injuries 14%-32%.
  - Increasing lead time reduces injuries and fatalities by as much as decreasing FAR in the 1986-2004 period and a 31 min tornado lead time is expected to decrease injuries by 40% or as much as 11-15 min lead time
  - A warned tornado reduced fatalities by about 30% and injuries by about 35% compared to a missed event
  - Between 1986-1999, NEXRAD **prevented 79 fatalities** and over **1,050 injuries per year**
    - Expected U.S. fatalities 34%-45% lower and expected injuries 35%-40% lower with a nearby NEXRAD
- **Impacts**
  - Tornado FAR of 50% and POD of 90% by 2025…saving lives and property
  - Tornado lead times of one hour, flash flood lead times of four hours, and four-fold reduction in QPE bias error by 2025…saving lives and property by at least as much as NEXRAD
  - Increased lead time allows for implementation of systematic mitigation and evacuation procedures
    - Schools, nursing homes and hospitals would have sufficient time to evacuate [OCCWS]

http://www.economics.noaa.gov/?goal=weather&file=events/tornado

Simmons and Sutter, BAMS, Jun2009

Goals/Targets:
Customer Needs

Goal/Target	Outstanding Issues
Raise probability of Detection (POD) to 90% without raising False Alarm Ratio (FAR)	Increased low-level kinematic data resolution
Lower tornado FAR to 50%	Socioeconomic impact of reduced FAR (reduction in fatalities and injuries, public response, reduction in damage; optimal communication strategy) Lack Warn-on-Forecast capability. FAR is related to observational resolution and knowledge of tornadogenesis.
Increased tornado lead time to ~1 hr based on WoF rather than merely detection	Socioeconomic impact guidance (e.g., actionable thresholds). Lack Warn-on-Forecast capability. Requires high-resolution boundary layer coverage and storm-scale models. Paradigm skill level needs to be established.
Improved effectiveness of public response and EM decision-making to severe weather warnings	Needed social science research is expensive and very local in applicability. Need improved dissemination of thresholded warnings and forecasts and understanding of public responses.

Goals/Targets:
Emerging Science & Technology

Goal/Target	Outstanding Issues
High-resolution (100m x 100m, 1-min) sampling of boundary layer.	No NEXRAD sampling below elevations of 0.5°. Few alternatives exist to fill observational gap, none inexpensive. Lack cost-benefit of satellite radiometry, dense surface meso/micronets, UAS-based and other supplemental sensor sampling. Resource limits may bound solution.
Storm-scale sensing of hydrometeors and related dynamics. Hydrometeor discrimination (type, amount, location). Doubled observational coverage in mountainous areas. Three-dimensional wind sensing in real-time.	Need to evaluate cost-benefit and performance of phased array weather radar alternatives though these are expected to outperform WSR-88D. Appropriate models need development. Testing must include complex terrain.
Four-fold reduction in QPE bias and four hour flash flood warning lead time. Ability to sample adaptively at higher resolution than background	Need systematic performance evaluation of sensor alternatives to determine cost-effectiveness. How to best leverage existing R&D efforts. Adaptive data integration technology needs systematic development.
Operational Warn-on-Forecast capability leading to large increases in severe weather lead times (e.g., POD=90%, FAR=50%, TOR lead time ~ 1 hr).	Need significant improvements in observational resolution and coverage (boundary layer), storm-scale NWP and data assimilation. How to best leverage existing R&D efforts.

Goals/Targets:
Emerging Science & Technology

Goal/Target	Outstanding Issues
Improved mesoscale specification and forecasting	Optimal mesoscale data assimilation technology is yet to be identified. Currently lack operational capacity for operational storm scale data assimilation or NWS-wide modeling.
Operational cloud-scale (ca. 100 m) NWP that includes hydrometeor type forecasting	Exists currently only in research community. Critical improvements to model physics still being identified. Currently lack operational computing capacity.
Improved real-time specification of severe thunderstorms to drive effective high impact decision support	Need development, testing and evaluation of real-time filling of thunderstorm sampling gaps with recursive and intelligent dynamic data mining and pattern recognition. Massive convective data sets will require sophisticated information extraction tools. Requires comprehensive developmental planning. OSIP?

Key Information Gaps

Gap	Solution Alternative	Impact
1. Pre-storm environment specification	1.1 Denser and greater sampling of boundary layer through polarimetric radar, satellite microwave, unmanned aerial sondes, micronets or combination 1.2 Mesoscale/cloud-scale analysis of observations	1.1 Convective initiation forecast, Verification/data assimilation 1.2 Verification/data assimilation Improved accuracy leading to longer lead time and probabilistic warnings for improved decision support.
2. Severe weather precursors	2.1 Rapid scanning of boundary layer with dual polarization radar 2.2 Rapid radar scanning (~ 1-min) 2.3 Interactive verification 2.4 Mix of 2.1-2.3 and space-based microwave radiometry	2.1,2.4 Hydrometeor discrimination. Increased lead time in proportion to new scan/current scan times. 2.2 Increased lead time in proportion to new scan/current scan times 2.3 Improved detection and warning Faster sheltering/mitigation response.
3. Warn-On-Forecast capability	3.1 High-resolution mesoscale/cloud-scale ensemble models assimilating high resolution boundary layer radar, surface, and microwave and infrared satellite data 3.2 Statistical and empirical algorithms	Probabilistic severe weather forecasting Model guidance Uncertainty Investment decisions Performance

Key Information Gaps

Gap	Solution Alternative	Impact
4. Unknown empirical thunderstorm predictability limits	4.1 Applied research of skill of model predictability of thunderstorm life cycle and propagation.	4.1 Intrinsic performance, investment decisions, knowledge of uncertainty, guidance on guidance, spatial warning uncertainty, mitigation
5. Societal factors: public understanding and communication	5.1 Integration of social science into hydrometeorologist formation 5.2 Targeted social research on how public uses warning information 5.3 Integration of decision support systems into NWS operations	5.1 Better targeted investments and decision support services 5.2 Better warning service 5.3 Meet customer driven decisional needs
6. Detection and Verification	6.1 Interactive verification database with data mining capability 6.2 High resolution (sub-1 km) observations of boundary layer weather	6.1 Better warning service performance 6.2 Better warning service performance and objective verification Improved accuracy of forecasts and uncertainty.

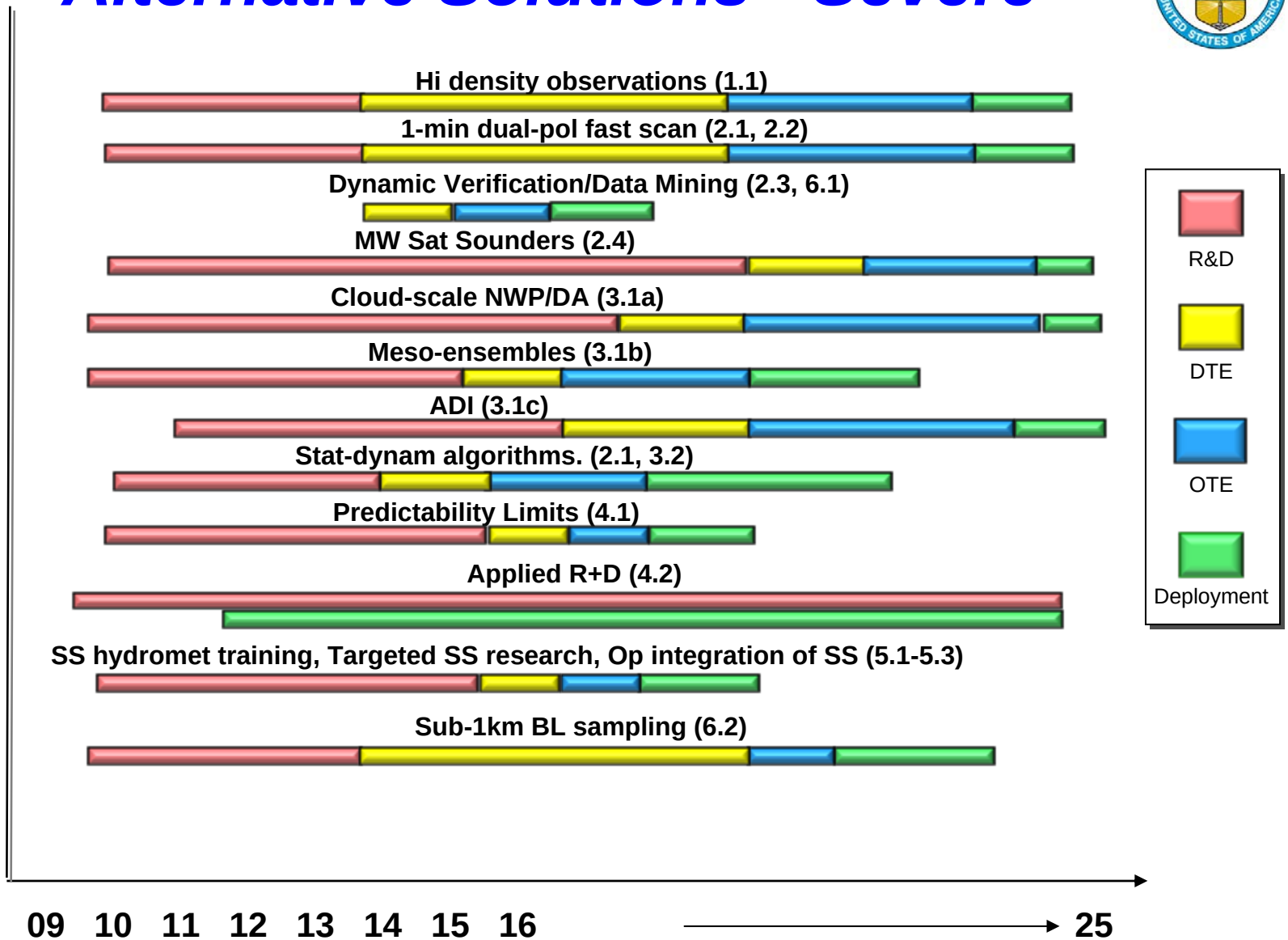
Research Needs and Opportunities

- **Short-term**
  - Research on socio-economic benefits and impacts of WoF on decision making
  - Hi-resolution radar data assimilation
  - Dual – Pol detection of tornado precursors
  - Observational and NWP resolutions needed to enable adequate WoF skill
  - Improved physical understanding of tornado formation and decay
  - Improved QPE dual-pol accuracy
  - Quantitative hydrometeor density estimation
  - Evaluate warning-generation software performance under multiple storm scenarios

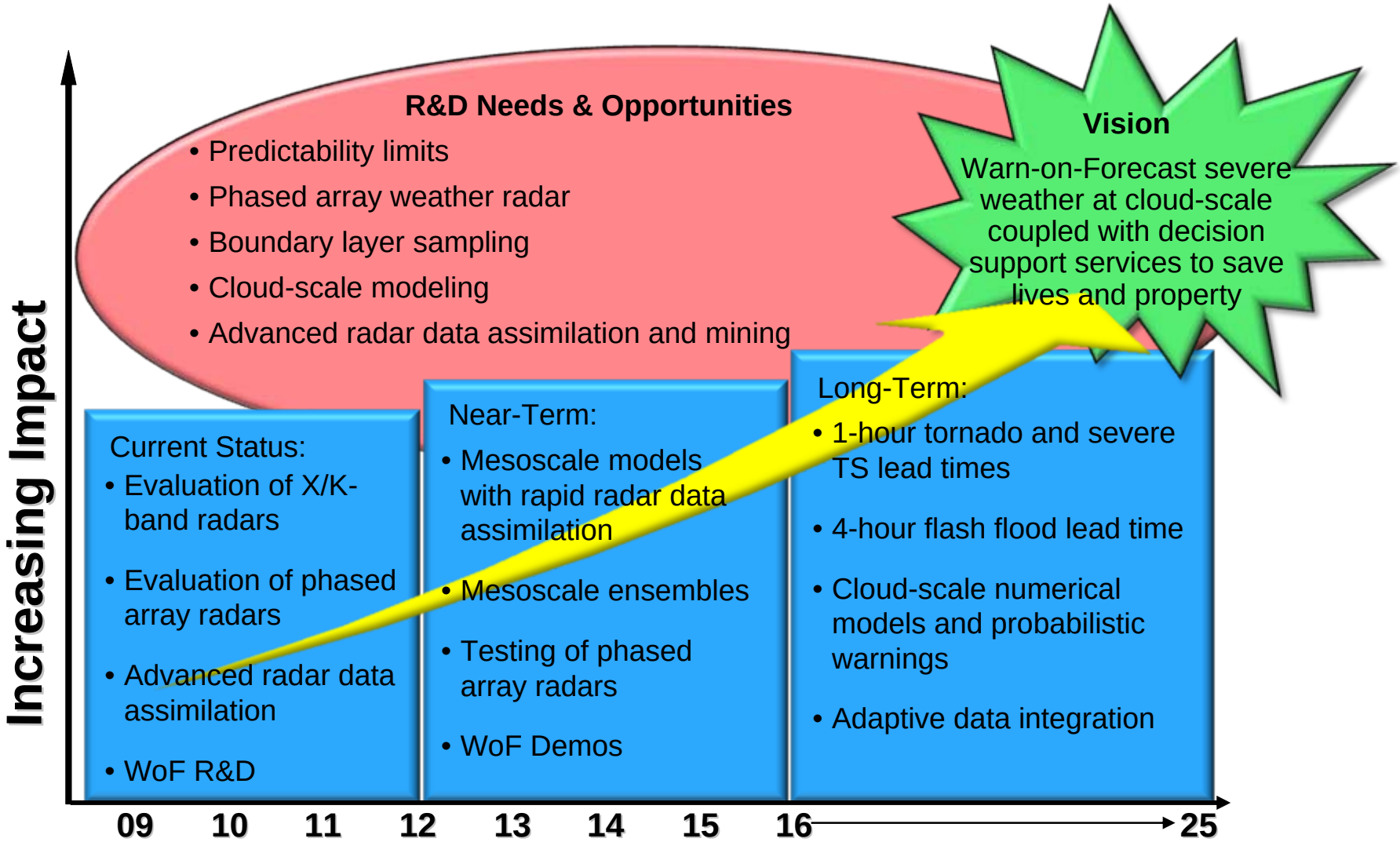
Research Needs and Opportunities

- **Long-term**
  - Skillful cloud scale model characteristics and performance including data assimilation
  - Determine limits of severe weather predictability
  - Establish appropriate approach for WoF probabilistic ensembles
  - Characterize effective decision support systems based on probability thresholds
  - Characterize severe weather microphysics
  - Hydrometeor type prediction

Alternative Solutions - Severe



Focus Area Team Summary: Severe Weather



Target Performance Measures: Severe Weather

Proposed	Current (2009)	FY 2016 Target Example	FY 2025 Target Example
Tornado Warning Lead Time	14 min (SBW)	20 mim	1 hour
POD	72% (SBW)	80%	90%
FAR	74% (SBW)	65%	50%
Severe Thunderstorm Lead Time	17 min (SBW)	23 min	1 hour
POD	77% (SBW)	85%	95%
FAR	44% (SBW)	35%	20%
Statistical Reliability	Not currently measured	Better than climatology	Better than baseline
Flash Flood Lead Time	66 min (SBW) 77 min (county)	1 hr	4 hours
POD	79% (SBW) 91% (county)	85% (SBW) 91% (county)	90%
FAR	43% (SBW) 58% (county)	40% (SBW) 40% (county)	30%
Probabilistic Reliability		Better than climatology	Better than baseline
Convective Initiation lead time	Not currently measured	10 min	60 minutes
POD	Not currently measured	Better than climatology	50%
FAR	Not currently measured	Better than climatology	50%
Statistical Reliability	Not currently measured	Better than climatology	Better than baseline

SBW = Storm-based warning