NOAA Global Systems Laboratory

User-Driven Decision Support

Daniel Nietfeld
Liaison to the National Weather Service
Chief, Weather Information Systems Evolution Branch

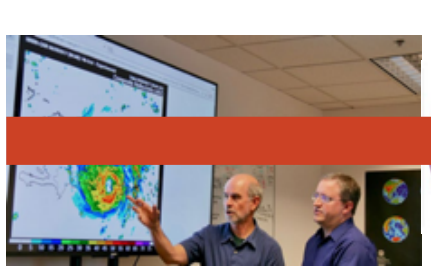
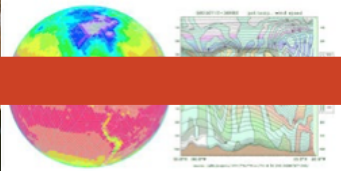
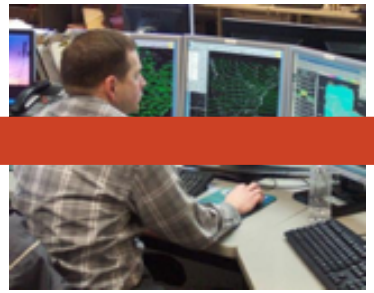
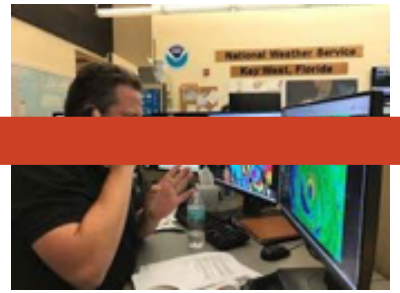
What does Decision Support Look Like?

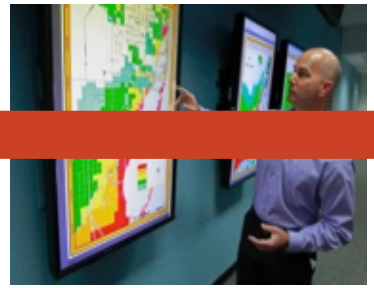
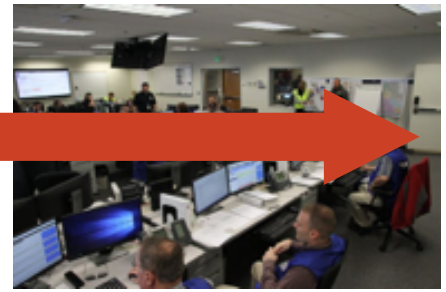
Meaningful Forecast Information

Model development producing forecast output

Operational Forecasters using and communicating the forecast model output

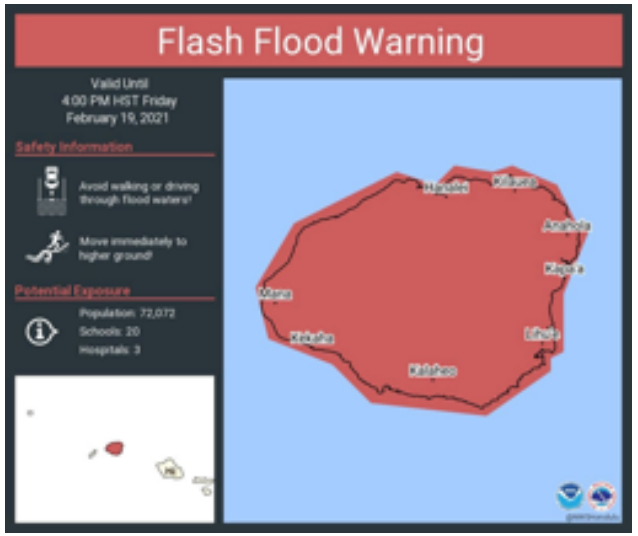
Core Partners making decisions based on the weather information provided

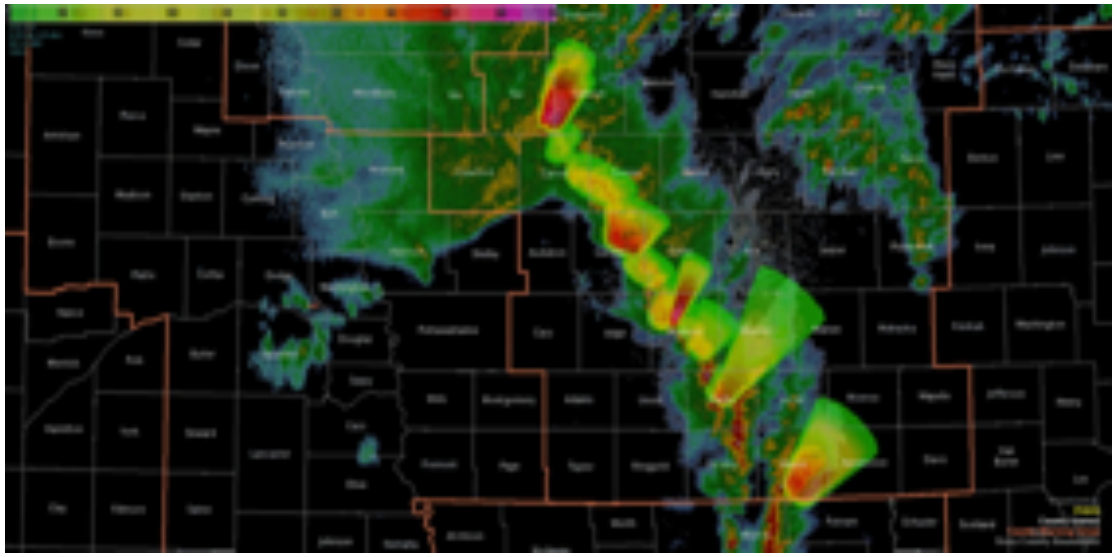



GSL Grand Scientific Challenge: *"Providing actionable environmental information through the delivery of global to storm-scale predictions and innovative decision support capabilities to serve society"*

Modernizing Warnings and Watches

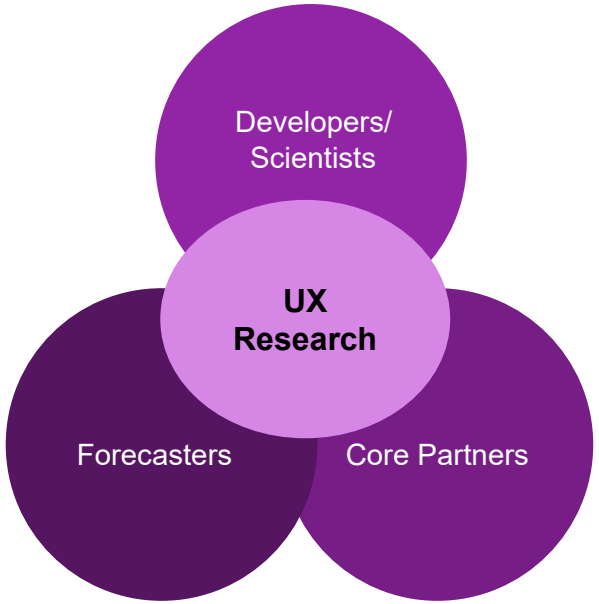


Hazard Services

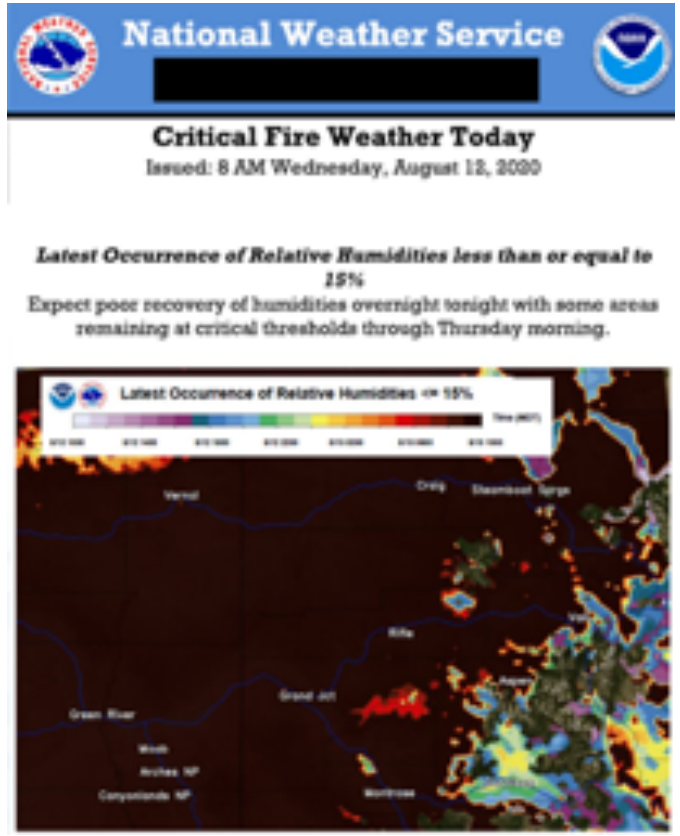


User Experience (UX) Research

Understanding information needs to influence designs



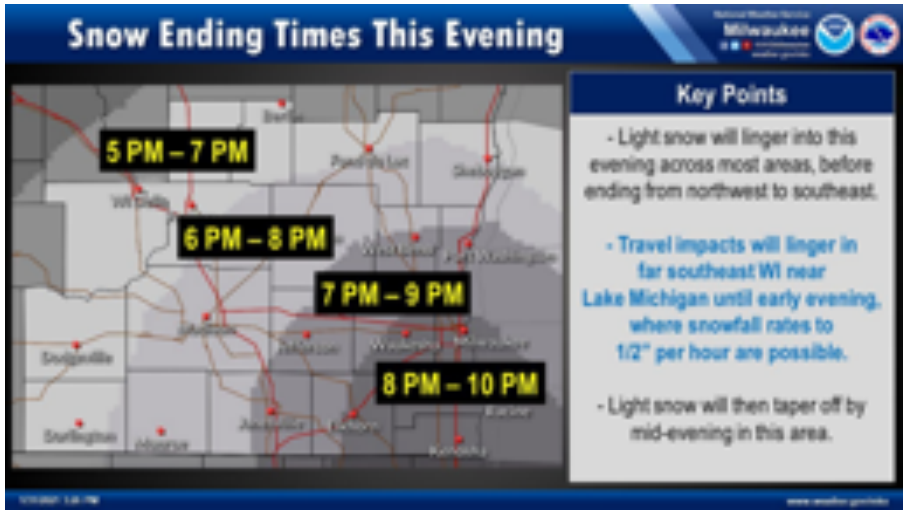
Social Science Research

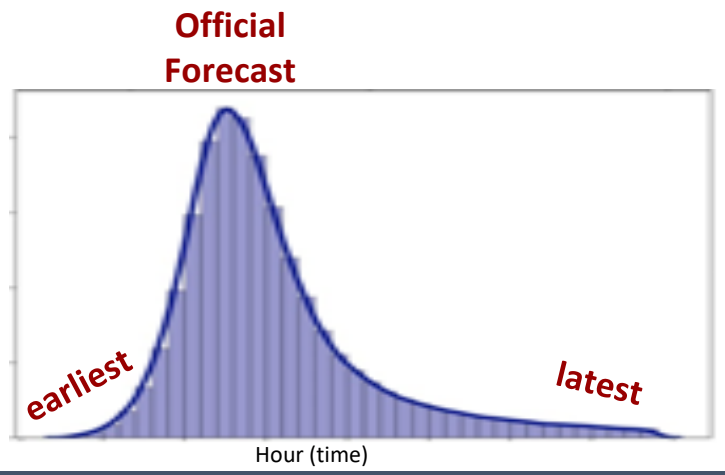


Actual NWS Fire Weather Briefing Graphic derived from timing uncertainty research

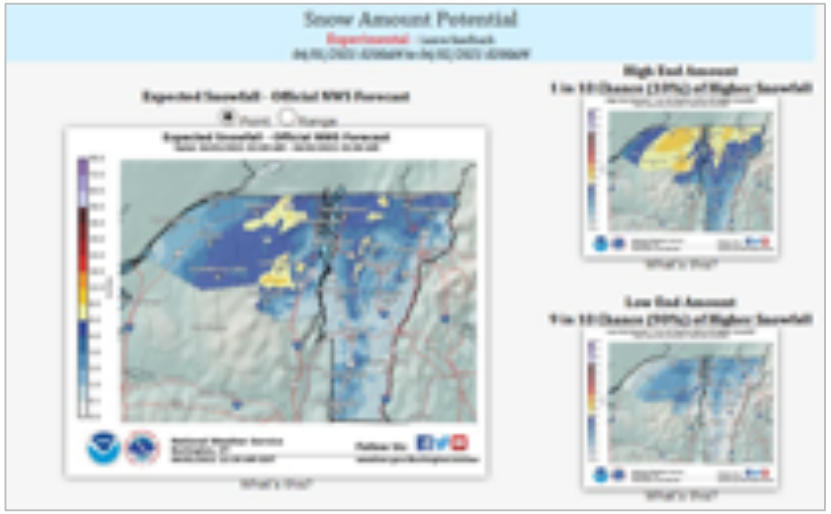
Uncertainty and Ranges of Possibilities

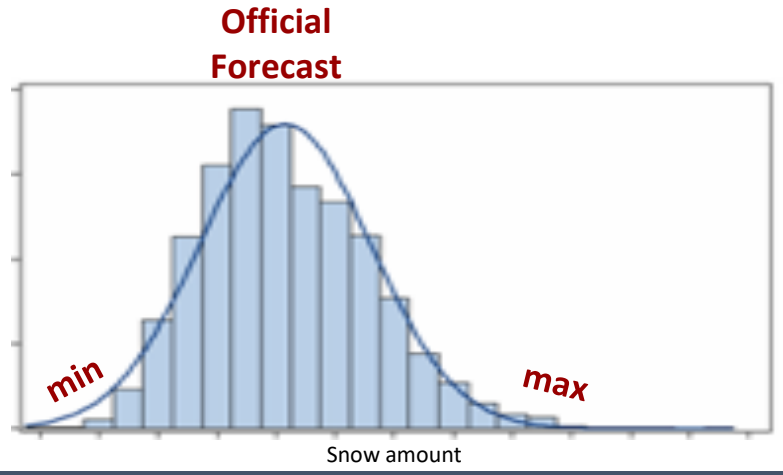
Timing Uncertainty



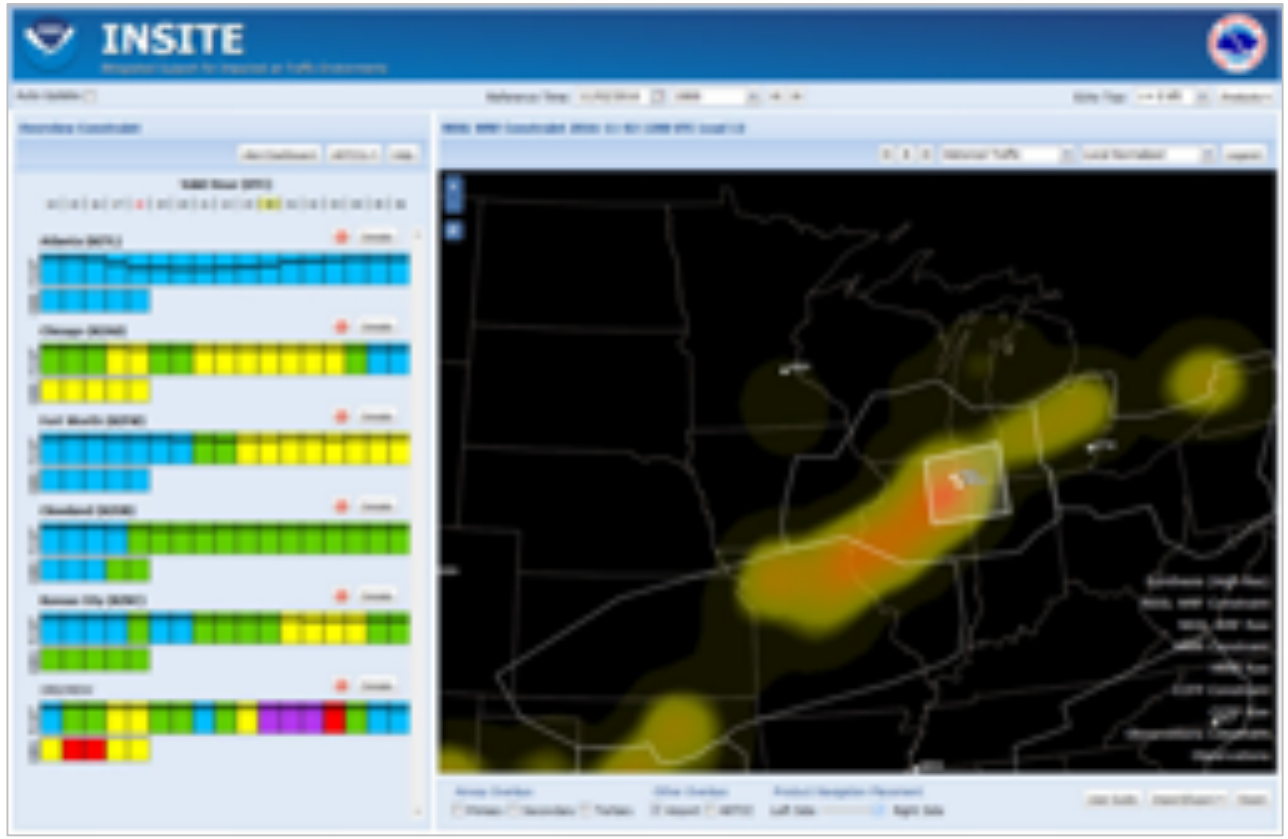


Magnitude Uncertainty





“How Confident Are You That This Will Happen?”

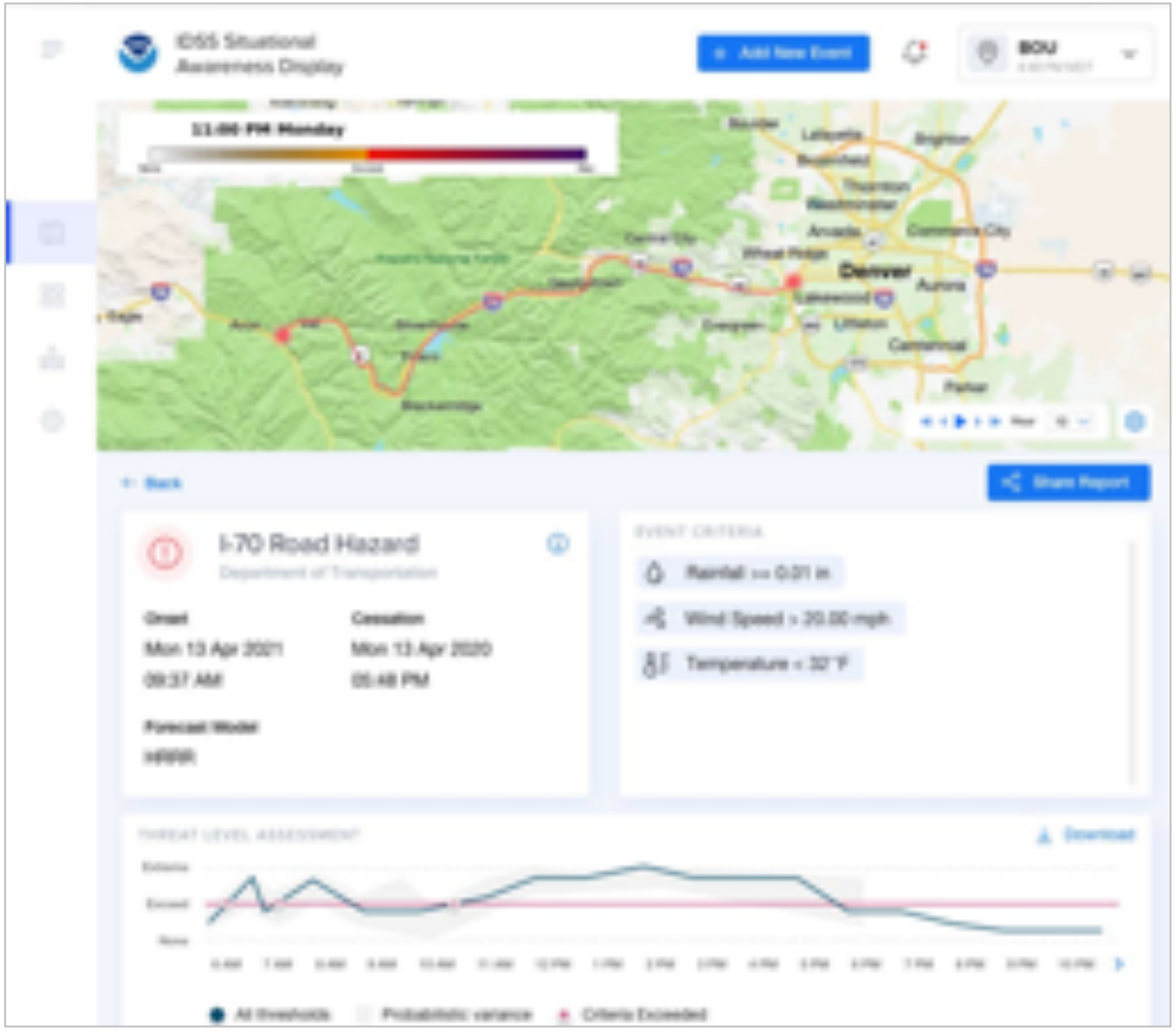


- Automated verification for forecast calibration and confidence
- Verification can influence forecasters’ confidence!

One of the first applications to quantify confidence based on past performance of forecast sources.

The IDSS Engine Project

- User Information Needs
  - Forecasters
  - Decision-Making Partners
- Ranges of solutions
  - Timing
  - Magnitude
  - Worst Case Scenarios
- Confidence
- Probabilities
- Data Mining
- Verification



From Previous Review

	Cloud Integration	Social Science Integration
	Recommendation (B6.1.1): *Invest in exploring the use of cutting-edge technologies such use of the 'Cloud' and the development on-demand information systems*	***Recommendation (D4.2.1):*** *Begin incorporating social science perspectives and knowledge into decision support activities*
ACTIONS	Migrated AWIPS to Amazon Web Services (AWS) cloud platform for evaluation by Natl. Interagency Fire Center Forecasters	IDSS Project to develop timing guidance for forecasters and partners - interdisciplinary team led by social scientist (Risk Communication)
	Conducted 3 Hazard Services evaluations using AWS cloud platform	IDSS System development using User Experience researcher

NOAA Global Systems Laboratory

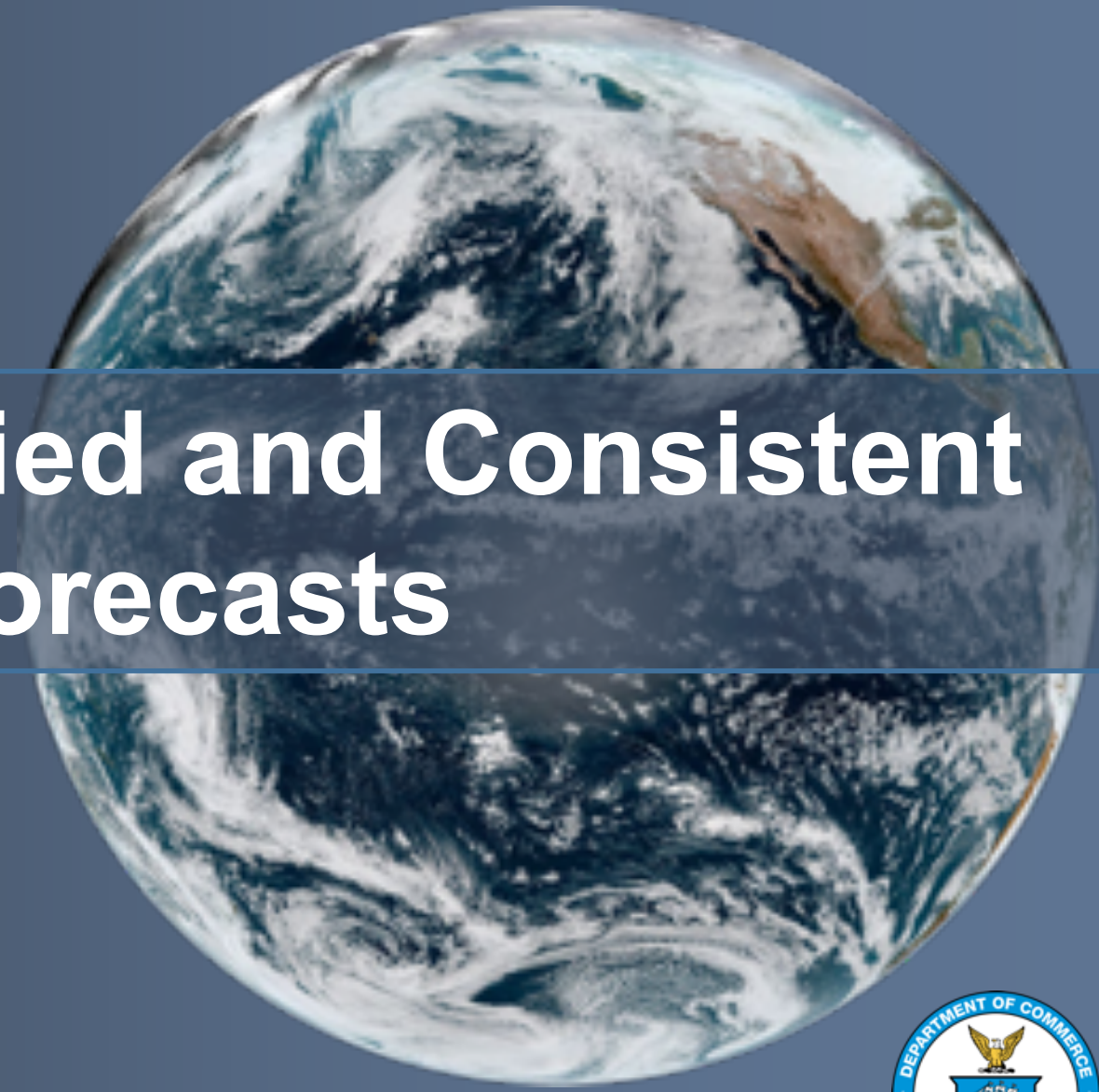
Decision Support Presentations

Decision Support

Decision Support Presentation Schedule

Presentation Topic	**Presenter**
Hazard Services	Darrel Kingfield
Hazard Services for National and International Centers	Nate Hardin
Implementing FACETs Concepts into Hazard Services	Kevin Manross
Combining Ensembles and Social Science to Enhance Decision Support	Ken Fenton
IDSS Engine	Daniel Nietfeld

NOAA Global Systems Laboratory



Hazard Services: Unified and Consistent Hazardous Weather Forecasts

Darrel Kingfield
Hazard Services Program Manager

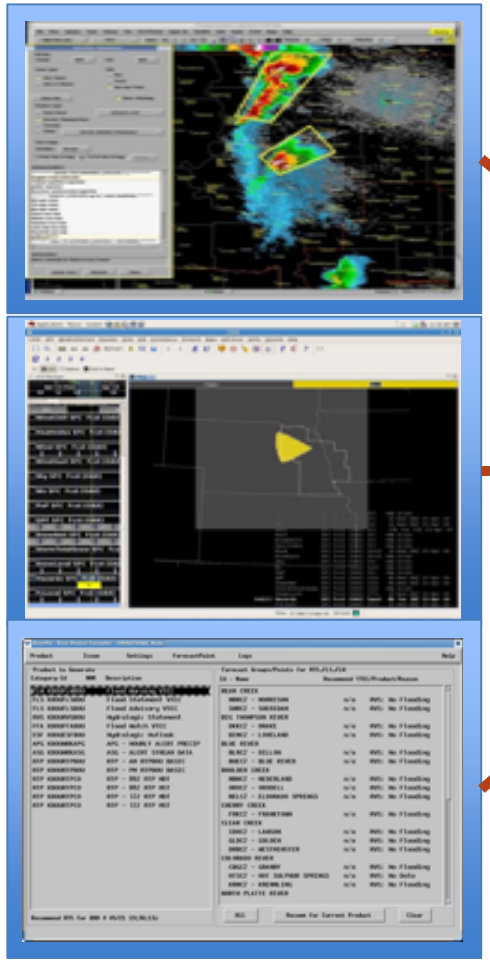
Global Systems Laboratory

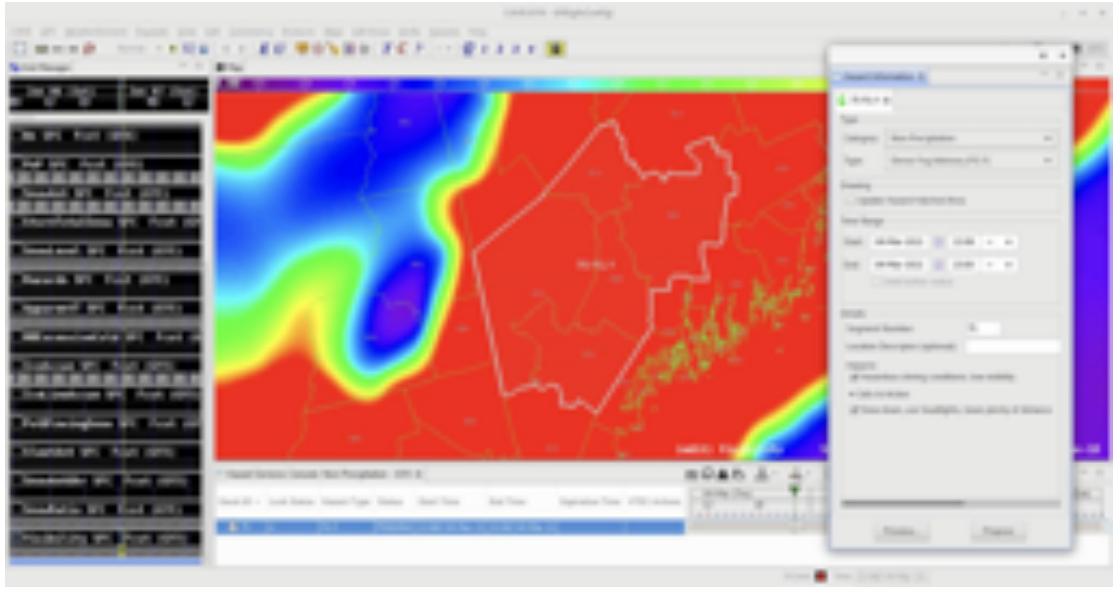
Hazard Services: The Backbone of a Weather Ready Nation

WarnGen

Graphical Hazard Generator

RiverPro



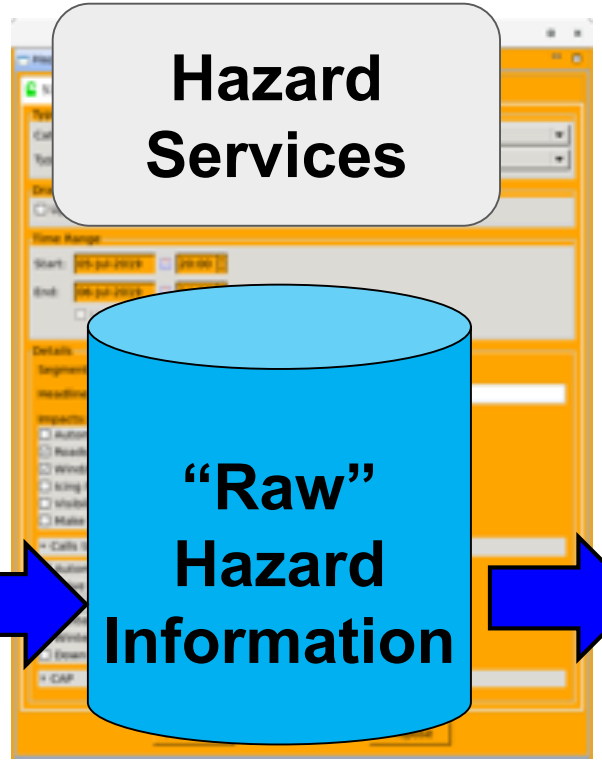


Hazard Services

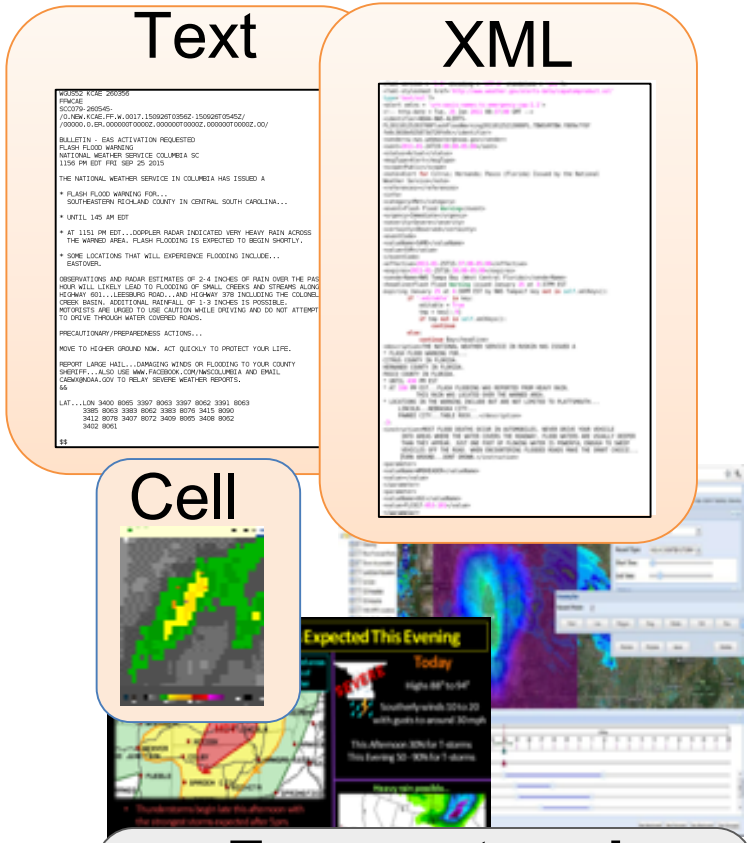
20-30 Year Old Hazard Forecasting Platforms

Multiple Communication Pathways

Forecaster analyzes the threat

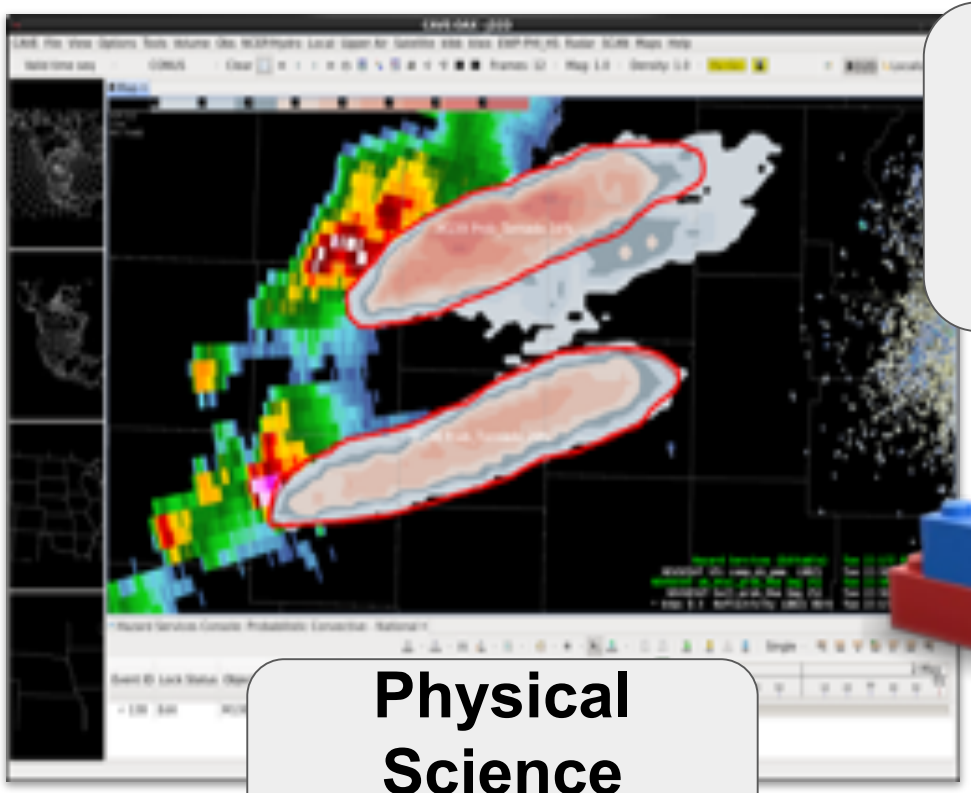


Forecaster describes the threat



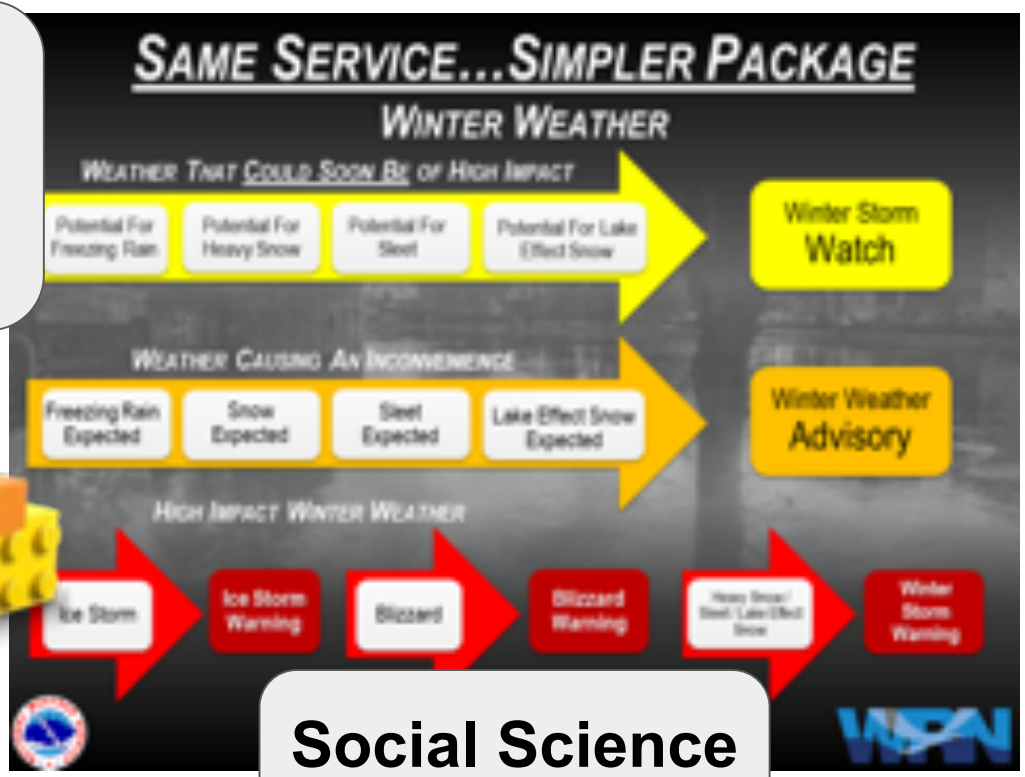
Forecast and warning products are produced

Fastlane for New Science to Operations



Physical Science Improvements

Highly Configurable Software Framework



Social Science Improvements

Flexible software framework allows for new science, policy, and technological improvements to be transformed into actionable information

Advancements since 2015: From Prototype to Operations

2015

Initial version migrated into the National Weather Service software development branch

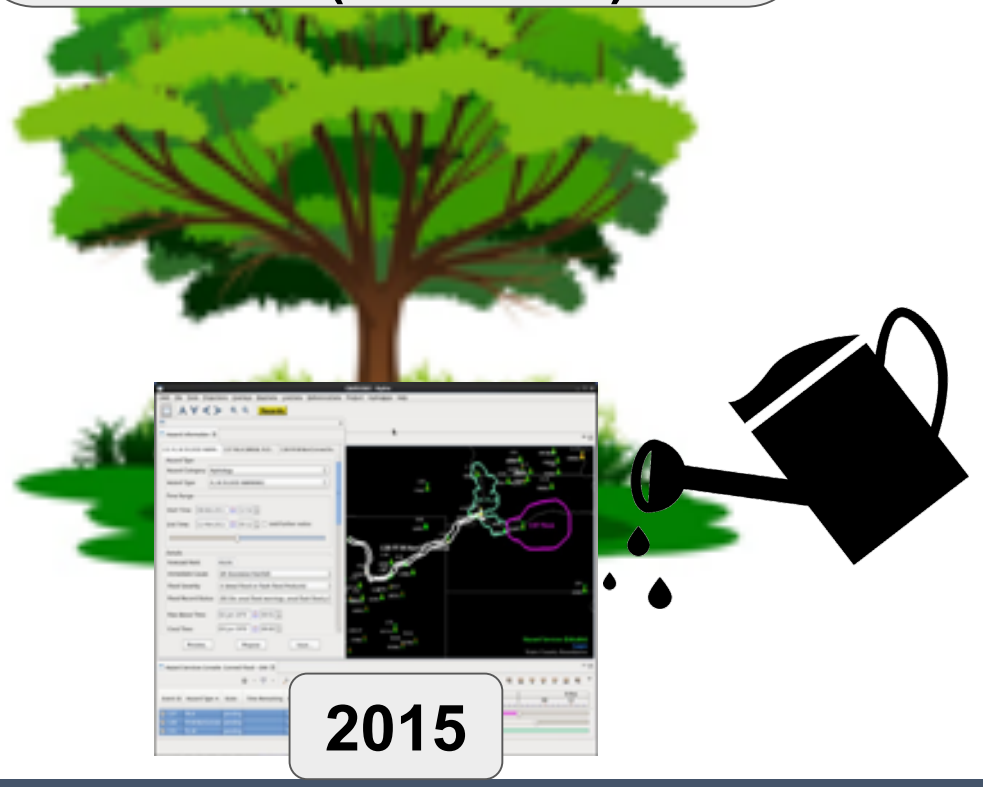
Continued development between GSL and Raytheon

2021

An operational platform installed at every National Weather Service office in the country

Some operational products issued for the public

A system that meets the needs of current users with new capabilities to serve broader sets of users (Rec. D4.6)



Hazard Services Implementation at National Weather Service Offices

Hydrology Hazards

12 hazard types

Operational since 2019

Hydrology Hazard Simplification

3 additional hazard types + language consolidation

Summer 2021

Winter Weather

13 hazard types

Operational at select sites

Nationwide in Fall 2021

Non-Precipitation Hazards

23 hazard types

Operational at select sites

Nationwide in Winter 2021/2022

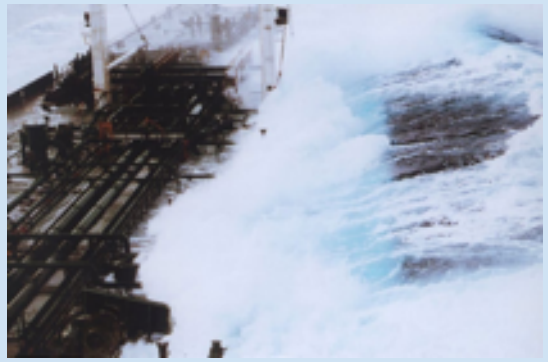
Ongoing Efforts for National Weather Service Offices

Convective Threats

10 hazard types

Initial Evaluation in Summer 2021

Marine



18 hazard types

Testing at select sites

Nationwide in 2024

Planned development efforts through 2025:

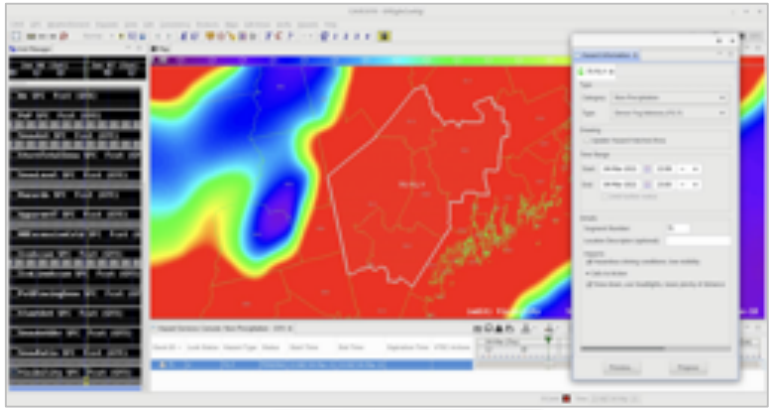
Fire Weather (3)

Non-Weather Emergencies (14)

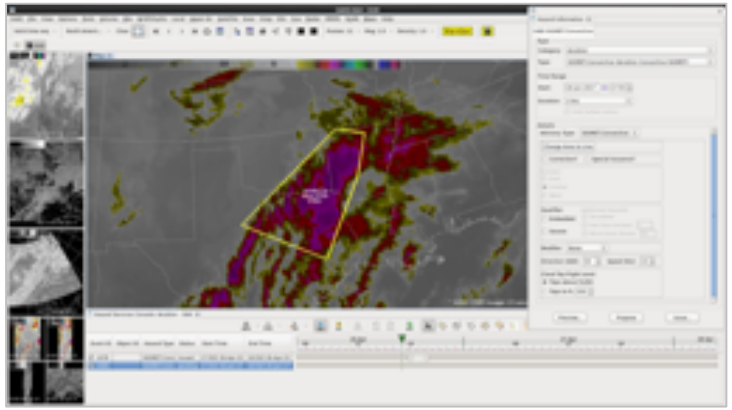
Tropical Weather (5)

Coastal Flooding (7)

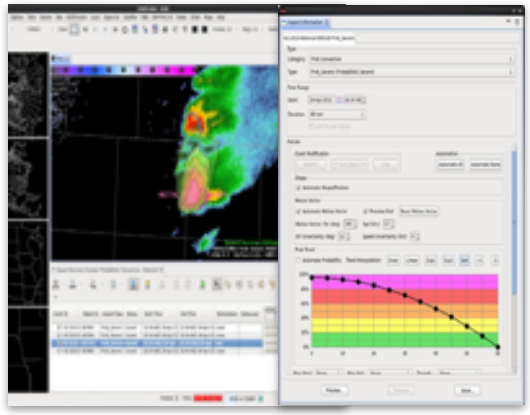
Shared Platform From Local To National Scales



National Weather Service Offices



National and International Centers



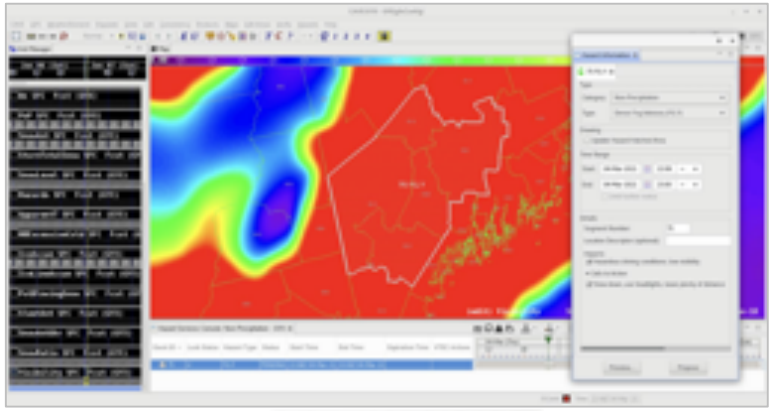
Forecasting a Continuum of Environmental Threats (FACETS)

NOAA Global Systems Laboratory

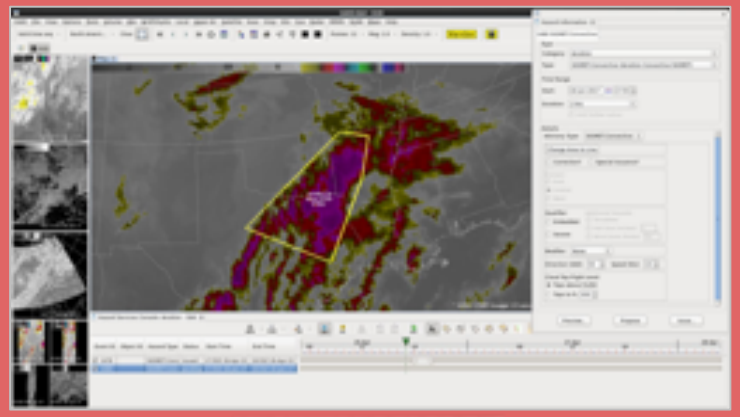
Hazard Services for National and International Centers

Nate Hardin
Program Manager for National and International Centers

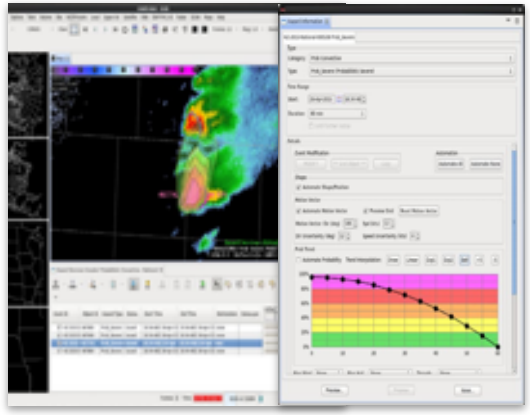
Shared Platform From National To Local Scales



National Weather Service Offices



National and International Centers



Forecasting a Continuum of Environmental Threats (FACETS)

Shared Platform From National To Local Scales

NATIONAL GUIDANCE → LOCAL MESSAGING

Evolving National and International Centers

National Centers:

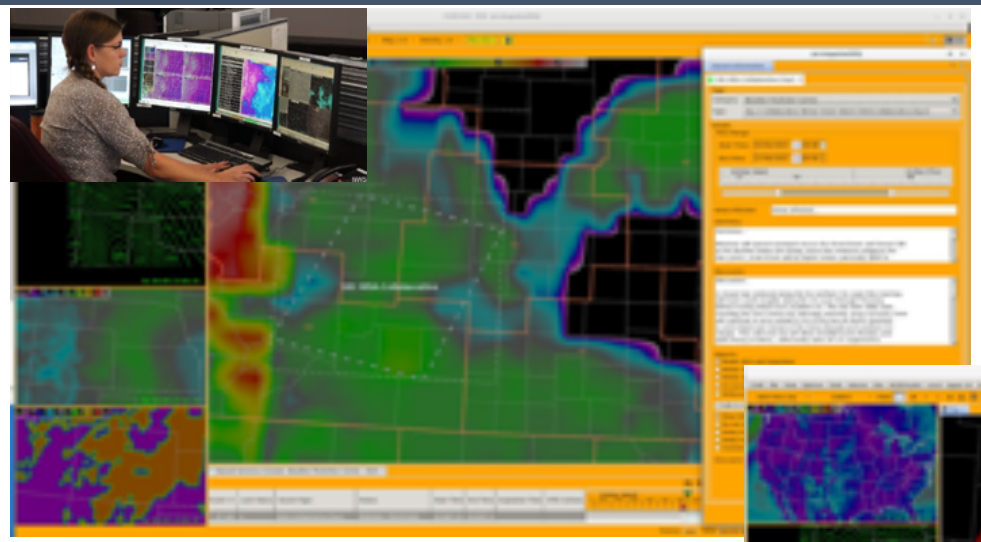
- NWS Strategic Plan 2019
  - Product Consistency (Objective *1.10*)
  - Common Operating Platform (Objective *1.11*)
  - Collaborative Forecast Process (Objective *3.5*)

International Centers:

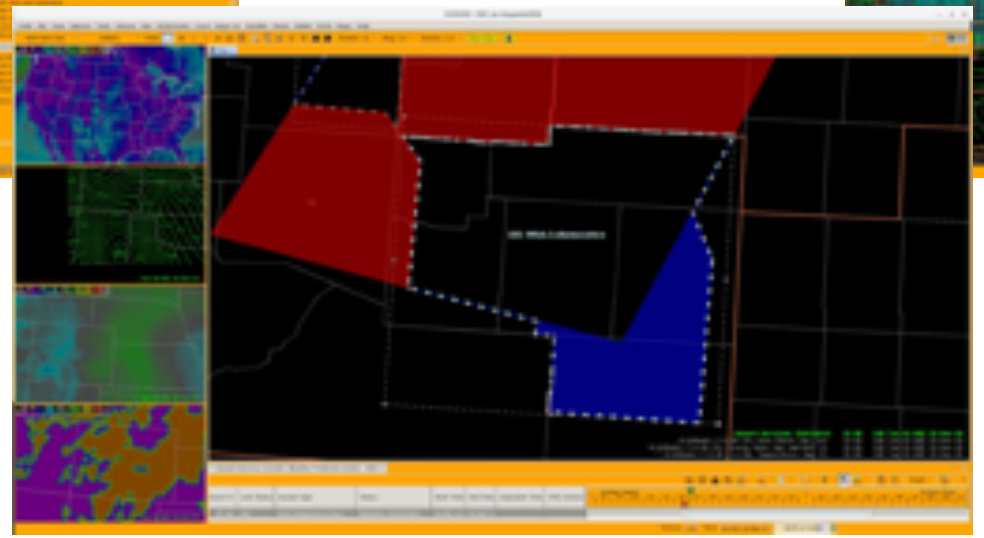
- Share life-saving R&D and extend technologies to new applications
- Mutually beneficial technological advancements with cost-sharing
- Strengthen foreign relationships

❖ This addresses Recommendations B6.6 and D4.1

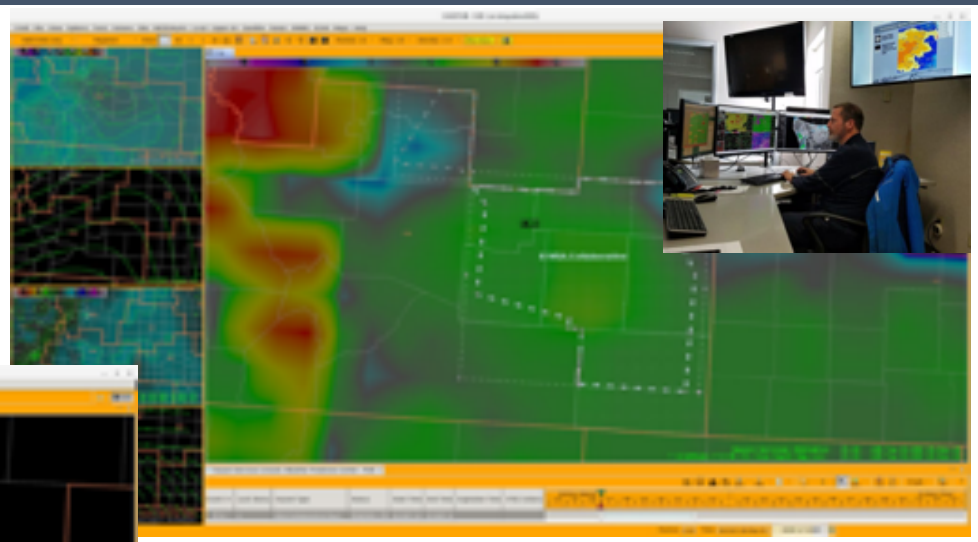
Benefits of Hazard Services in Operations



National Center forecaster creates product and initiates collaboration with impacted WFOs



National Center interprets collaborative differences and finalizes collaborative product for local WFO dissemination



Impacted WFO forecaster modifies spatial extent using local knowledge and expertise, then sends product back to the National Center

✓ Common Platform

✓ Collaborative Forecast Process

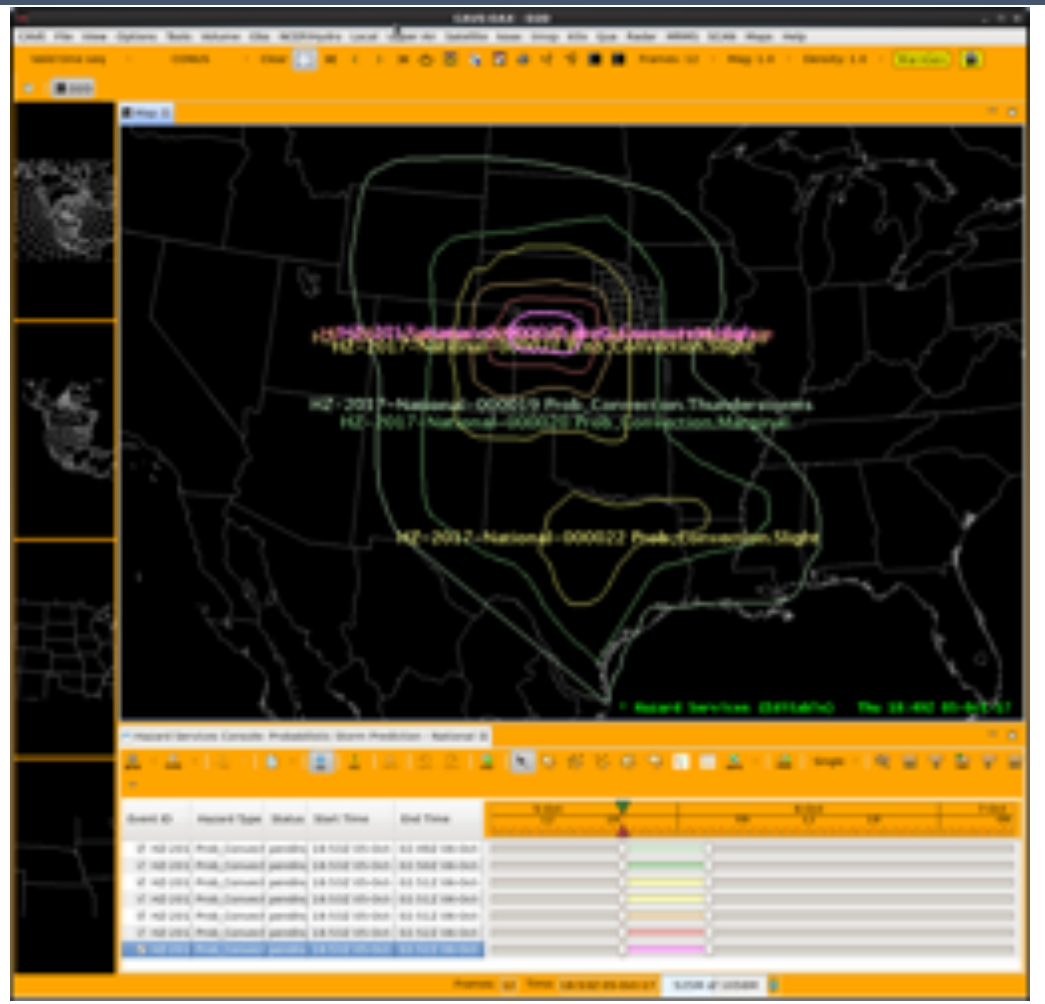
✓ Product consistency

Looking Back (2015): A Path Forward

HAZARD SERVICES IS THE WAY

Goals:

- Strengthen/Develop Partnerships
- Proofs-of-concept & Prototypes
- Secure exploratory funding



Prototype of Storm Prediction Center's Convective Outlook using Hazard Services

Accomplishments Since 2015: National Centers

Aviation

Common Operating Platform

FY 16-20

In Evaluation

High Seas

Collaborative with updated outputs

FY 19-21

Evaluation FY21 Q4

Excessive Precipitation

Common Operating Platform

FY 19-21

Evaluation FY21 Q4

Winter Weather

Collaborative with WFOs

FY 19-21

Evaluation FY21 Q4

Storm Surge

Collaborative with WFOs

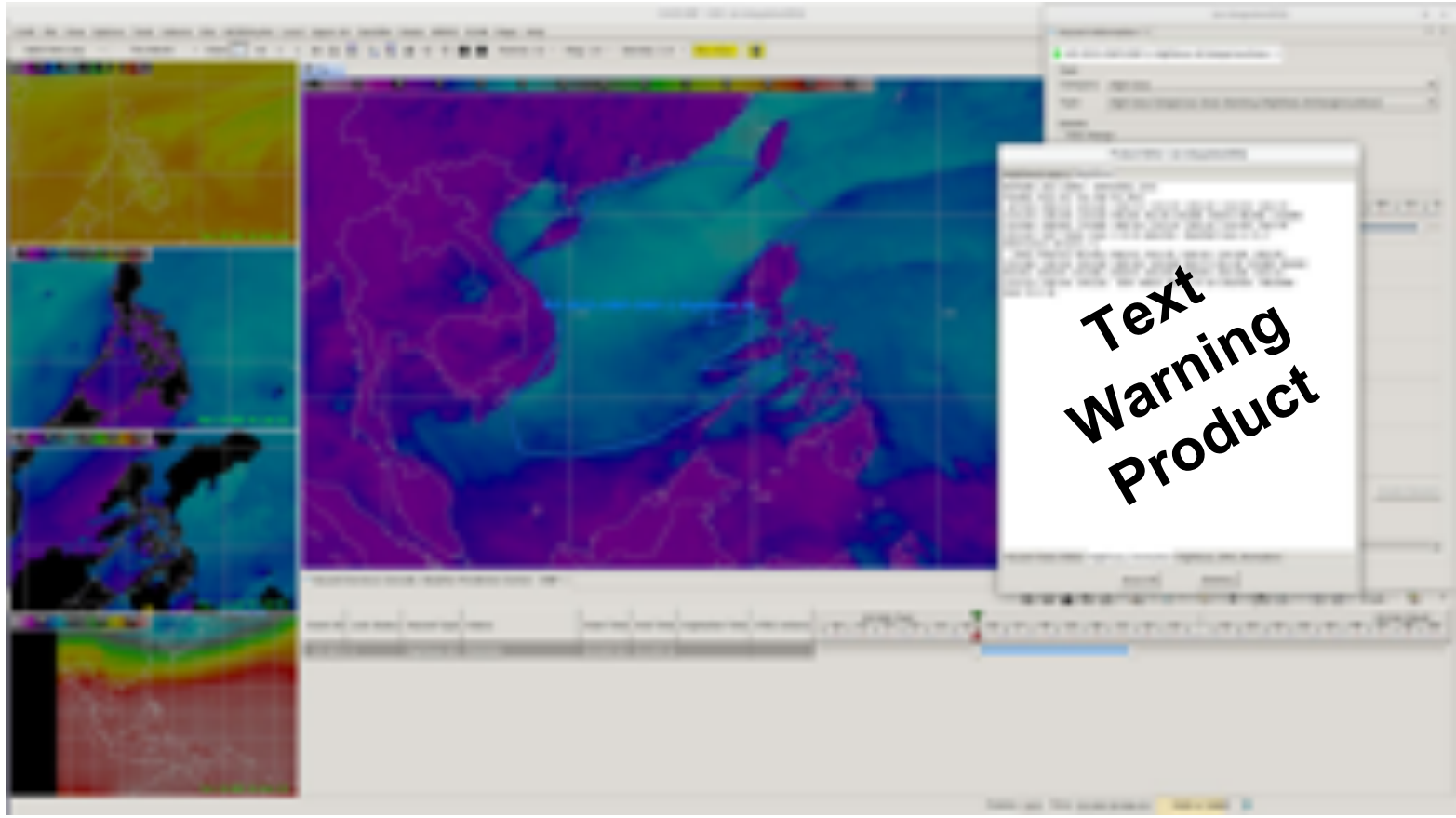
FY 18, 20-22

Under Development

Accomplishments since 2015: International

- Agreement to deliver HS capabilities for Taiwan's Central Weather Bureau

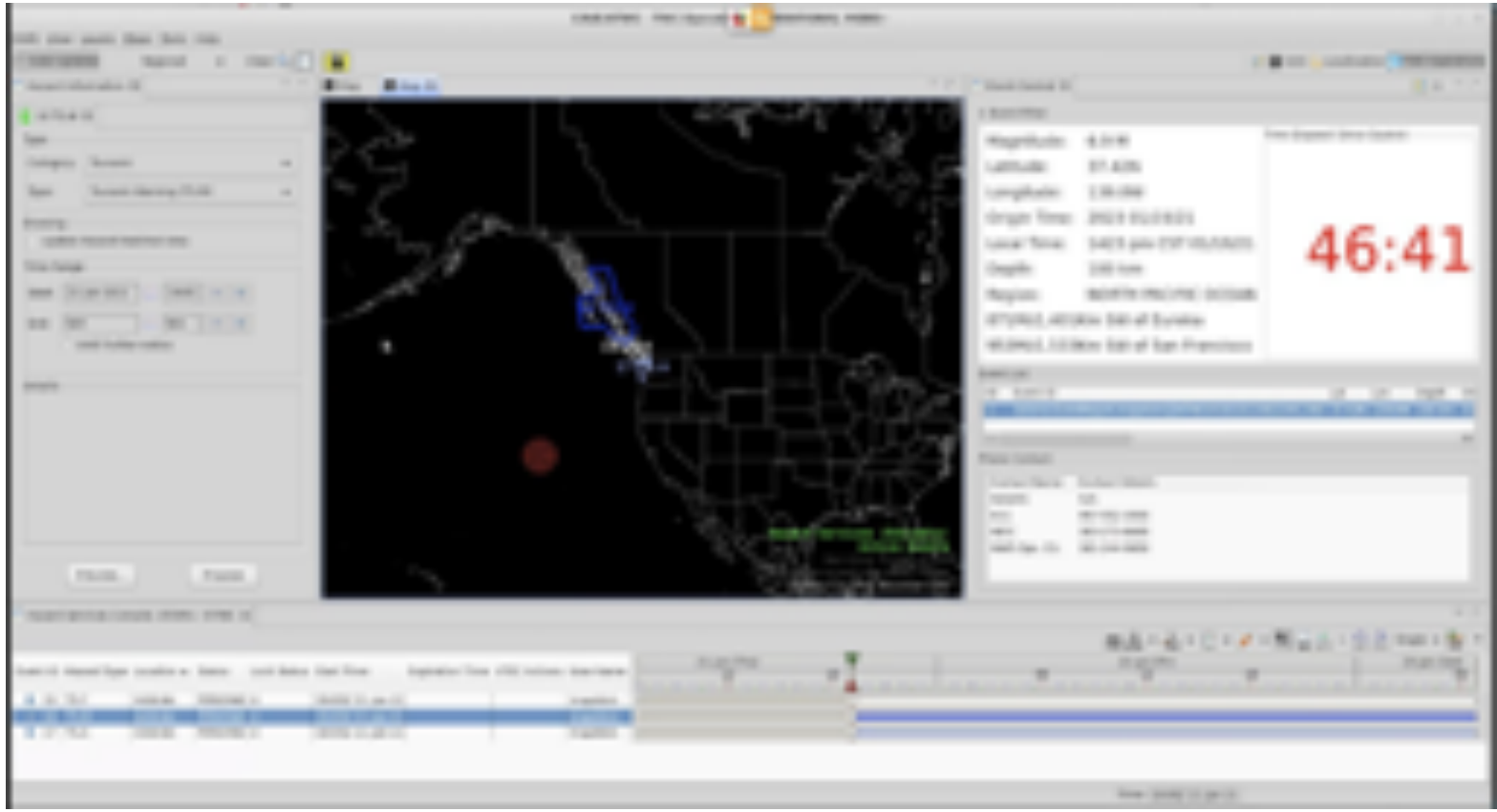
- Developing partnership to deliver HS capabilities for the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA)



Prototype Dangerous Seas Warning for PAGASA

Looking Forward to 2026: National Centers

- Continue to make inroads at all NCEP centers
- Move existing projects towards operations *(requires NWSHQ support)*
  - Tsunami Warning Centers
  - Ocean Prediction Center
  - National Hurricane Center
  - Weather Prediction Center
  - Aviation Weather Center



Tsunami Warning functionality in Hazard Services

Looking Forward to 2026: International

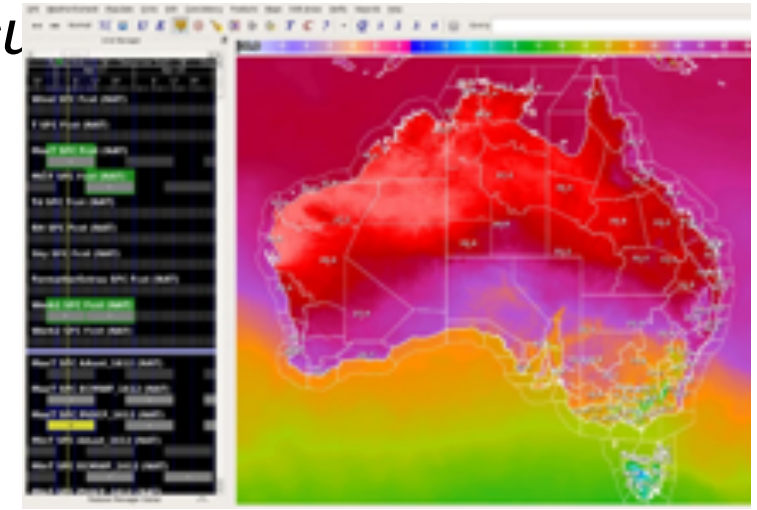
Bureau Of Meteorology (Australia) -- *Decision Support applications*

Central Weather Bureau (Taiwan) -- *HS for all hazards*

Civil Aeronautics Administration (Taiwan) -- *Aviation In-Flight potential*

Ocean Affairs Council (Taiwan) -- *High Seas & Tsu*

PAGASA (Philippines) -- *HS for all hazards*

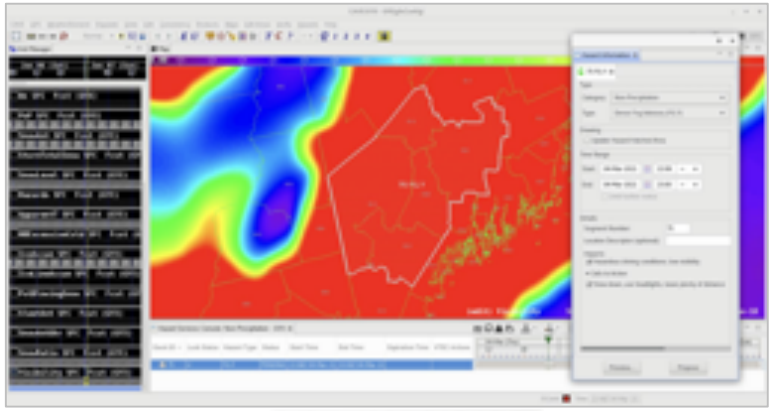


NOAA Global Systems Laboratory

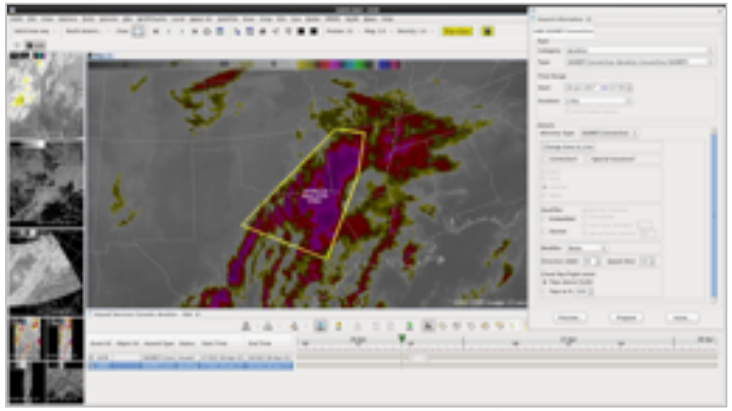
Implementing FACETs Concepts into Hazard Services

Kevin Manross
FACETs Project Lead for Hazard Services

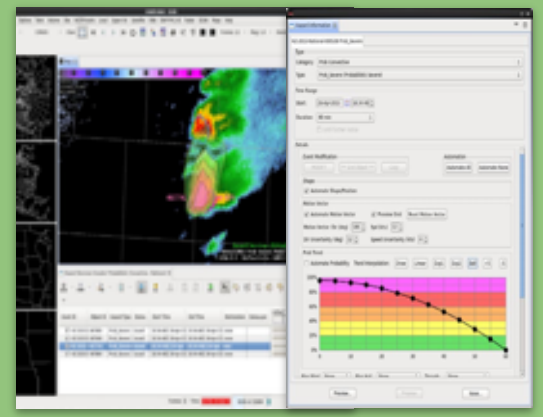
Uncertainty in Impact Weather



National Weather Service Offices



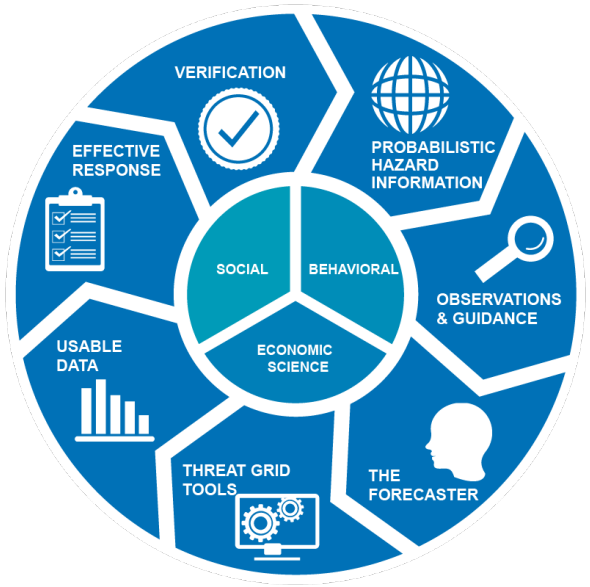
National and International Centers

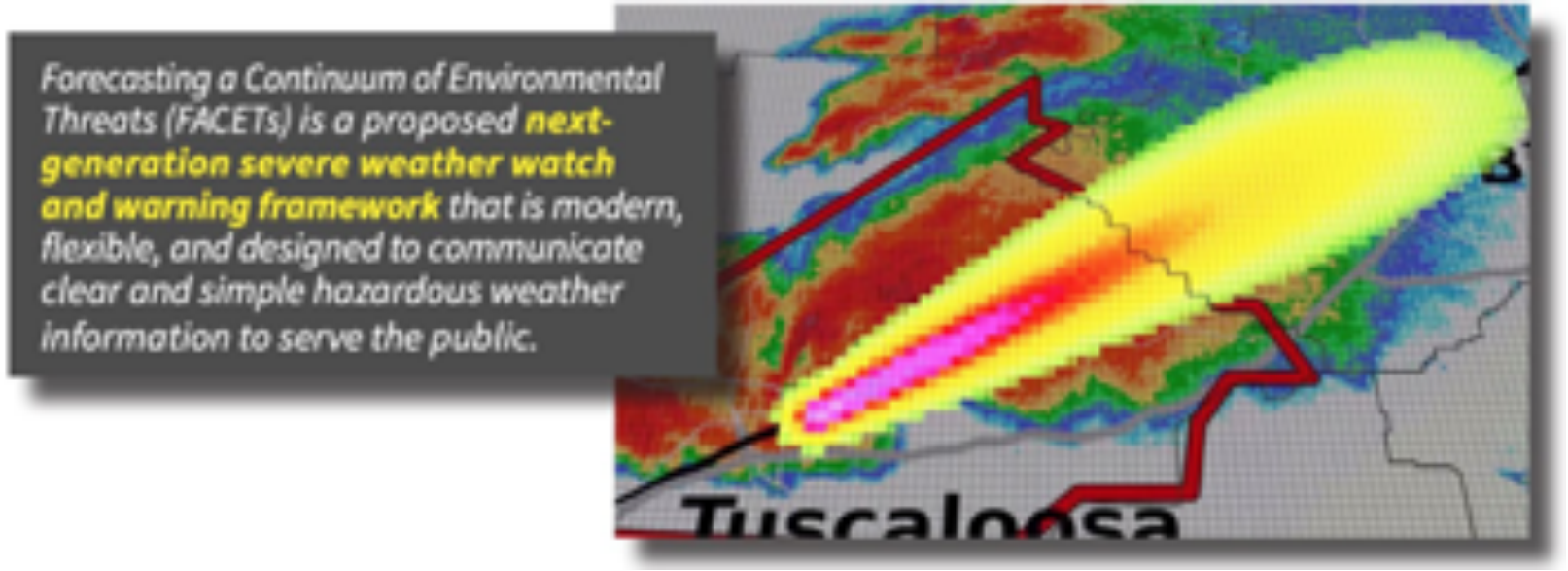


Forecasting a Continuum of Environmental Threats (FACETS)

Motivation

"... FACETs is designed to replace the NWS's 1960s-era deterministic (yes/no), ... with a modernized, science-based system delivering a continuous stream of high-resolution, probabilistic hazard information extending from days to within minutes of an event."





-Forecasting a Continuum of Environmental Threats (FACETs) Science and Strategic Implementation Plan (SSIP) October 2014

Motivation

FACETs:

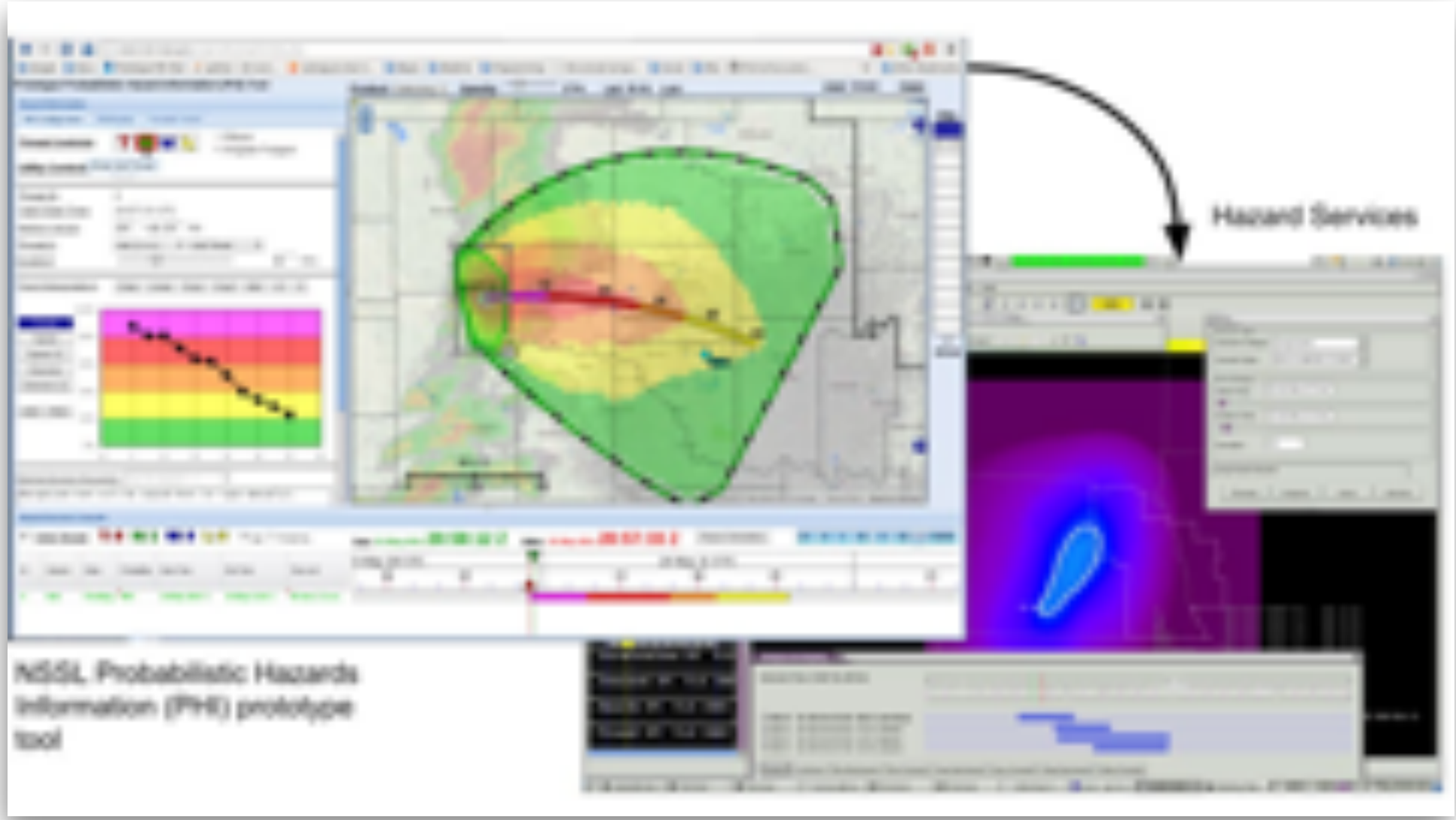
- NWS Strategic Plan 2019
  - Cuts across almost all of the objectives for Goal 1 "Transformative Impact-Based Decision Support Services (IDSS)"
  - Directly aligns with the "Systems, Technologies, and Tools" and "Research to Operations and Operations to Research (R2O/O2R)" of Goal 2

Previous NWS Strategic Plans echoed many of these concepts and were the drivers for this innovation

What We Were Trying to Achieve

How do we add uncertainty information to NWS Warnings

2015 Proposal



What We Were Trying to Achieve

From the 2015 Review

D4.1 Improve partnerships with national level programs to complement current efforts to support forecasters in the field. Perhaps opportunities like FACETs and WRN pilot programs could serve as shared initiatives to better integrate the efforts.

Researchers - including GSL, NSSL physical and social scientists and engineers - work with participants (forecasters, broadcasters and emergency managers) at the NOAA Hazardous Weather Testbed in October 2019

Strong Collaborative Ties

This R2O project has strong collaboration between OAR Labs as well as with NWS offices and external partners.

- NSSL, AFS, STI, Social & Behavioral Sciences (SBES)

Dr. Chen Ling (Univ of Akron), a human factors expert, discusses workload with NWS forecasters at the HWT in Feb 2020

Project Progress

Hazard Services-Probabilistic Hazards Information (HS-PHI)

- Ability to add uncertainty information to convective warnings

Threats in Motion (TiM)

- Rapidly (low as 1-minute) updates of warning polygons

A NWS forecaster setting a probability trend for a storm in the Hazardous Weather Testbed

Project Progress

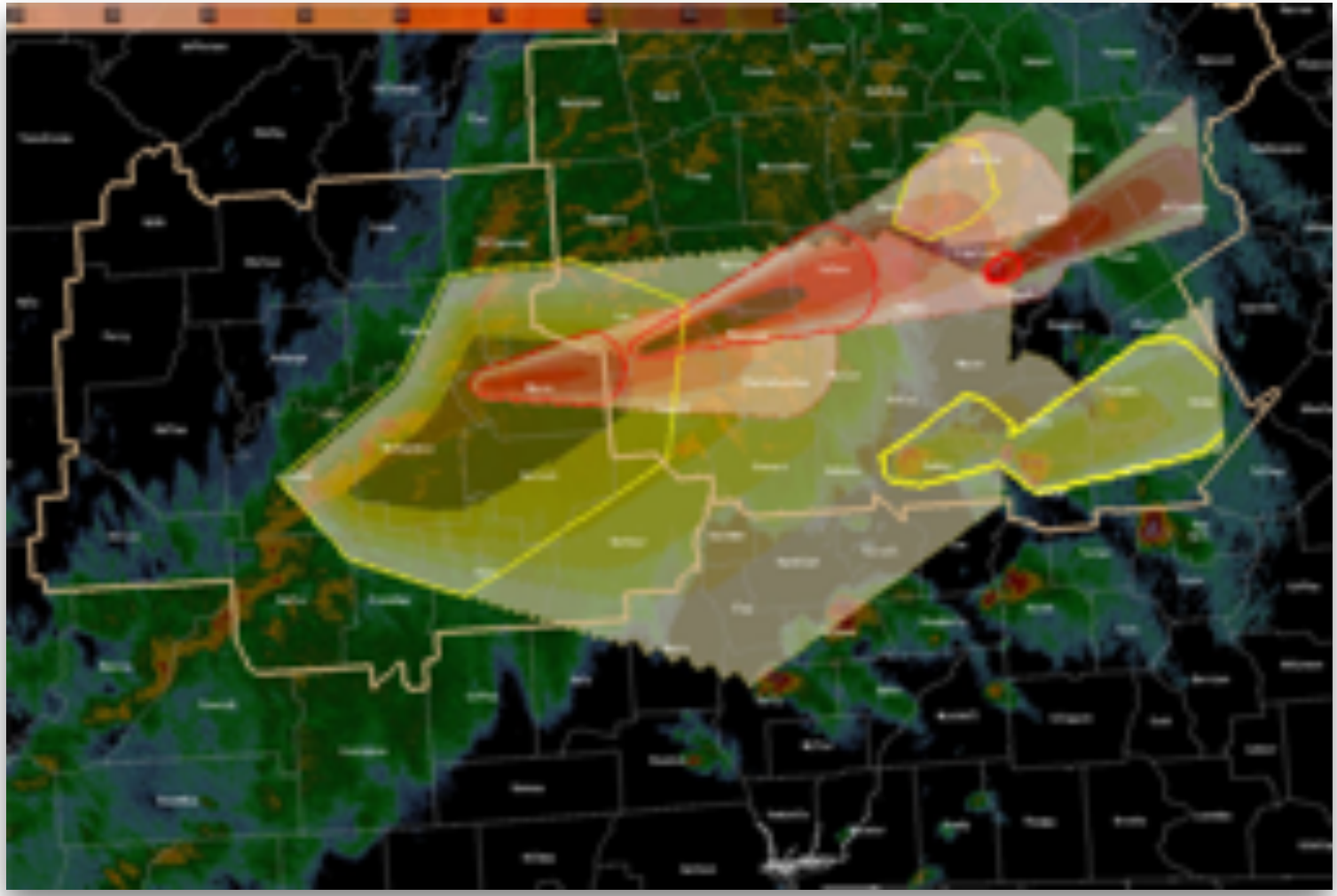
An animation showing the output from HS-PHI and TiM

Shaded areas indicate <u>probability</u> of hazardous weather impacting an area at that gridpoint (PHI)

- yellows = hail/wind
- reds = tornado
- darker = higher probability

Solid lines are <u>warnings</u> being translated along the motion vector (TiM)

- yellow = hail/wind
- red = tornado



Project Progress

Numerous HWT tests

- 2016, 2017, 2018, 2019, 2020
  - Virtual HWT Scheduled for July 2021

Maturing code to be migrated into operational code base (turned off until NWS policy allows)

Project Progress

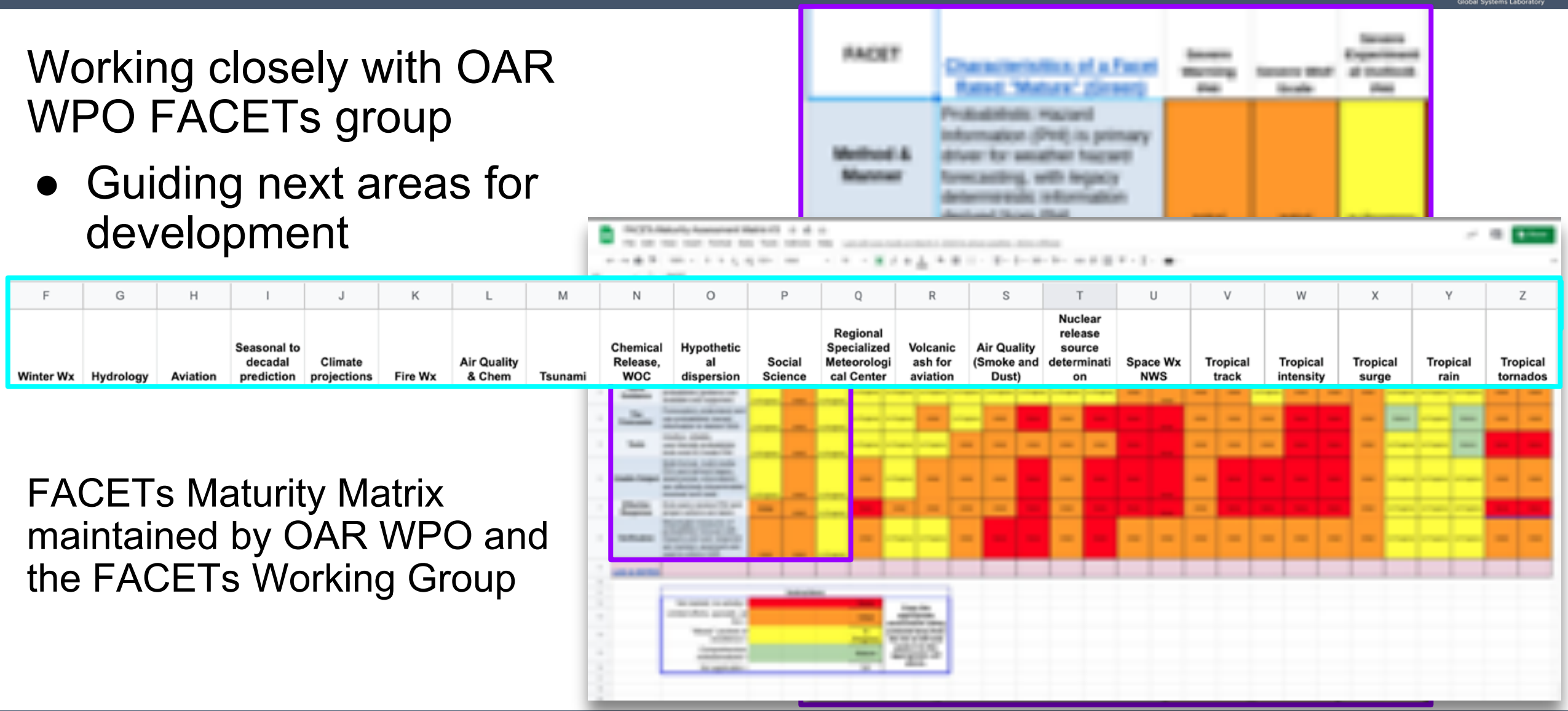
Integrated Warning Team:

- Forecasters
- Broadcasters
- Emergency Managers
- Researchers
  - Physical Scientists
  - Social Scientists
  - Engineers

Where Are We Going?

Working closely with OAR WPO FACETs group

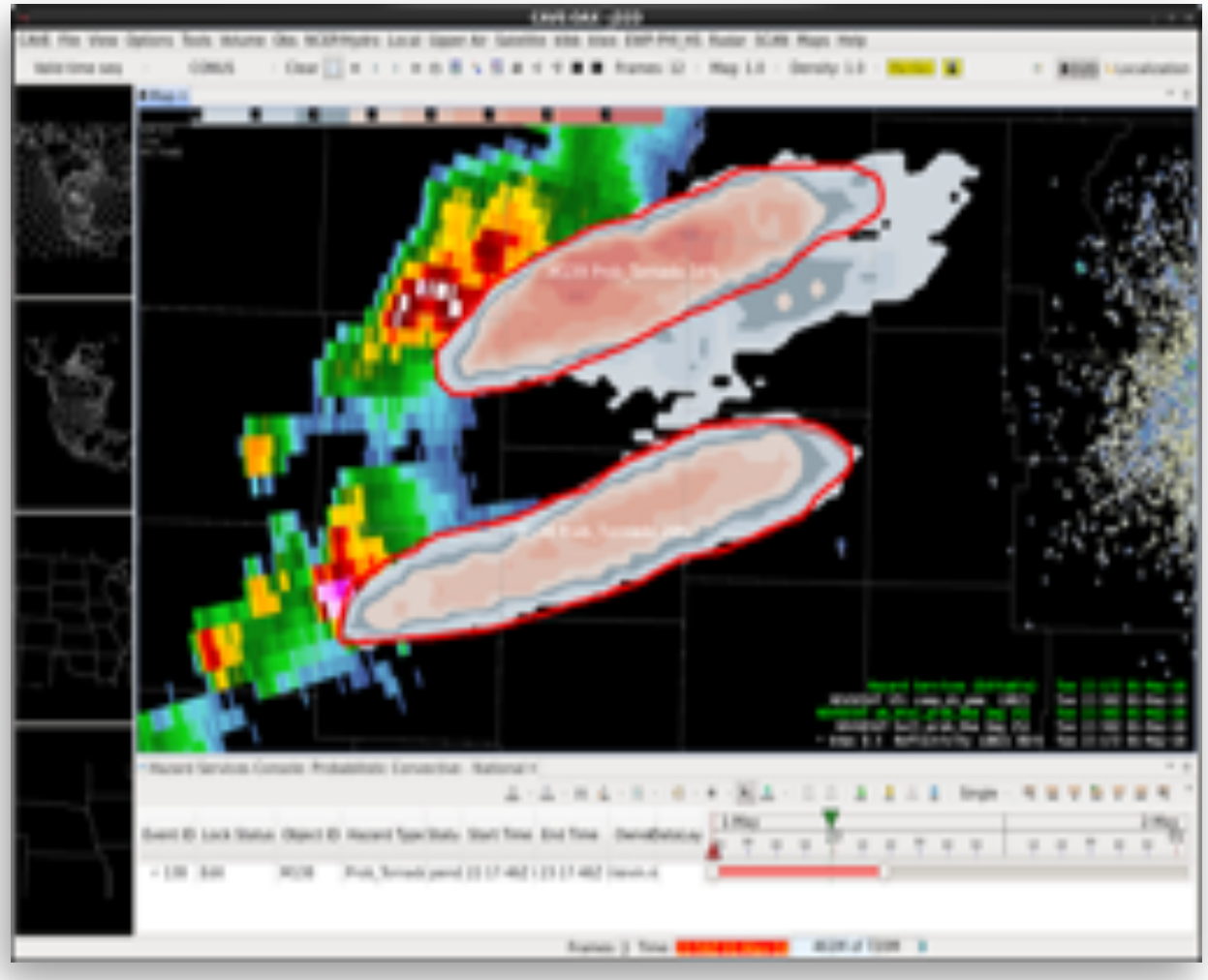
- Guiding next areas for development



FACETs Maturity Matrix maintained by OAR WPO and the FACETs Working Group

Where Are We Going?

Utilizing objective probability information in Hazard Services recommenders to create first guess fields for warnings



Warn-on-Forecast ensemble updraft helicity probability forecast plumes overlaid with radar data

Summary

- For the past 5 years, Hazard Services has updated to include the capability to add probabilistic information to severe thunderstorm and tornado warnings
- Threats in Motion has also been implemented in Hazard Services
- As the FACETs approach gains steam in NOAA OAR and NWS, GSL is playing a critical role in the R2O process

NOAA Global Systems Laboratory

Combining Ensembles and Social Science to Enhance Decision Support

Ken Fenton
Physical Scientist

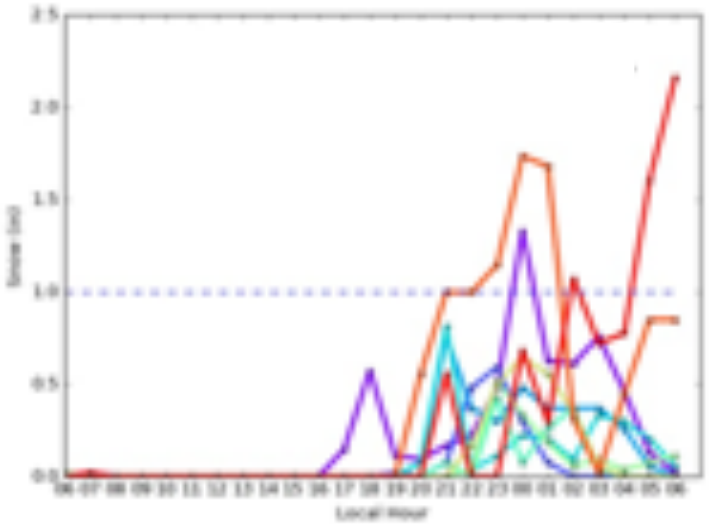
Global Systems Laboratory

Project Objectives

- Improving Convection-Permitting Ensemble Based Uncertainty Communication for Decision Support using the Weather Archive and Visualization Environment (WAVE)
  - Partnership with NCAR - Grant: #NA18OAR4590362
  - Crosses all GSL Divisions

How do we communicate ensemble guidance that enables better decisions?

HRRR Ensemble Snow Forecast



?

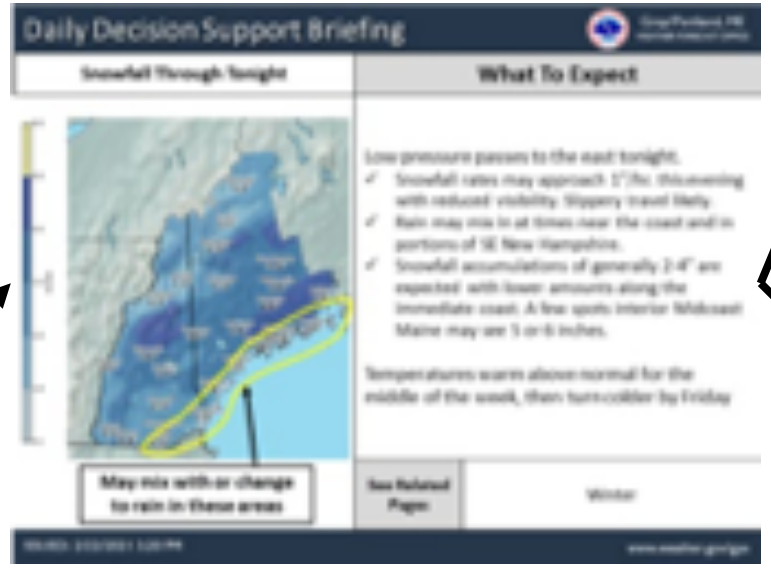
Actionable Decision Support

How Do Forecasts Affect Decisions?

Model Guidance

NWS Forecasters

Forecast & IDSS

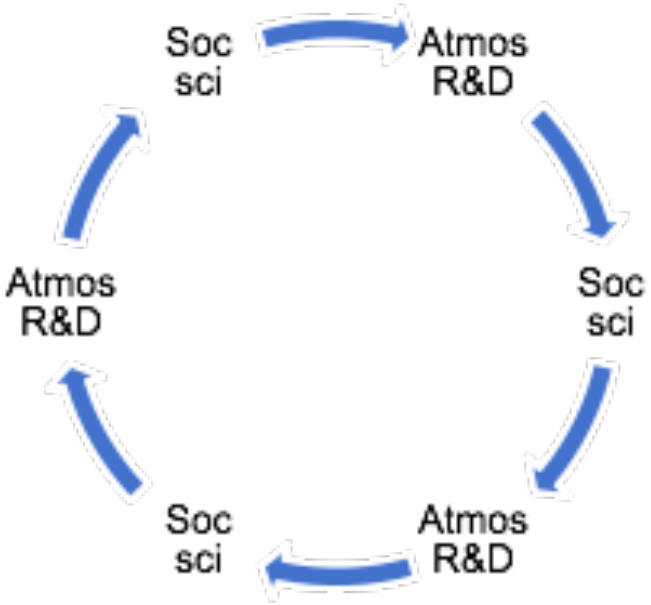


Partners

Members of the public

Iterations of Social and Atmospheric Science

- **Round 1**: Interviews with 9 forecasters and 10 partners
  - Confirmed need for map-based timing information
- **Round 2**: Initial derivation of timing guidance and verification prototypes
- **Round 3**: Interviews with 8 forecasters and 18 partners
  - Feedback on prototypes and additional needs
- **Round 4**: Additional timing guidance and refinement of visualizations
- **Round 5 *(current)***: Real-time forecaster use and survey evaluation



- Outcome: Recommendations to OAR and NWS

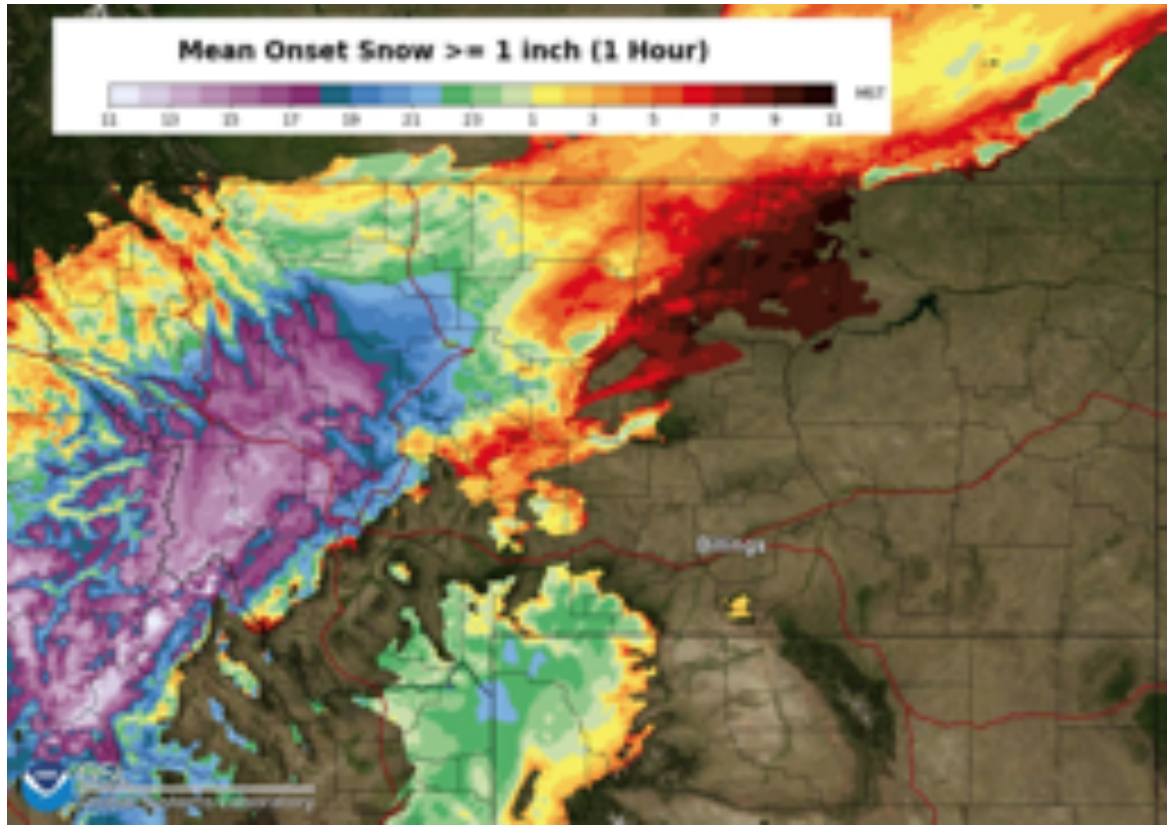
Interview and Development Cycle

It's not just the magnitude of the event, but **the timing is critically important**. If you bring in **even just an inch of snow, but it's right in the morning rush hour, well, now they cannot plow because there's all the cars in the road, and it's just a mess**. And then you wind up with a lot more accidents [...]. **So timing is probably one of the questions that we get asked the most: when is it going to start, and when is it going to end?**

NWS forecaster #28

From interviews conducted by NCAR and GSL social scientists

Focused on Fire Weather and Winter Weather



Visualizations developed by GSL meteorologists and software engineers

Interview and Development Cycle

Need for cessation information

"I've been part of **closing the interstate** enough times […] You can tell that within an hour or so that those **[wind] speeds are going to decrease at the location that we need it to. But then if you continue to watch it—we've had discussions like, "Do not open the interstate." Because the visibility is going to reduce again in less than an hour**. So those types of things are really important. They're **major for decision making because if you're going to have a lag in wind speeds for an hour and then they're going to pick back up, that's a huge issue."**

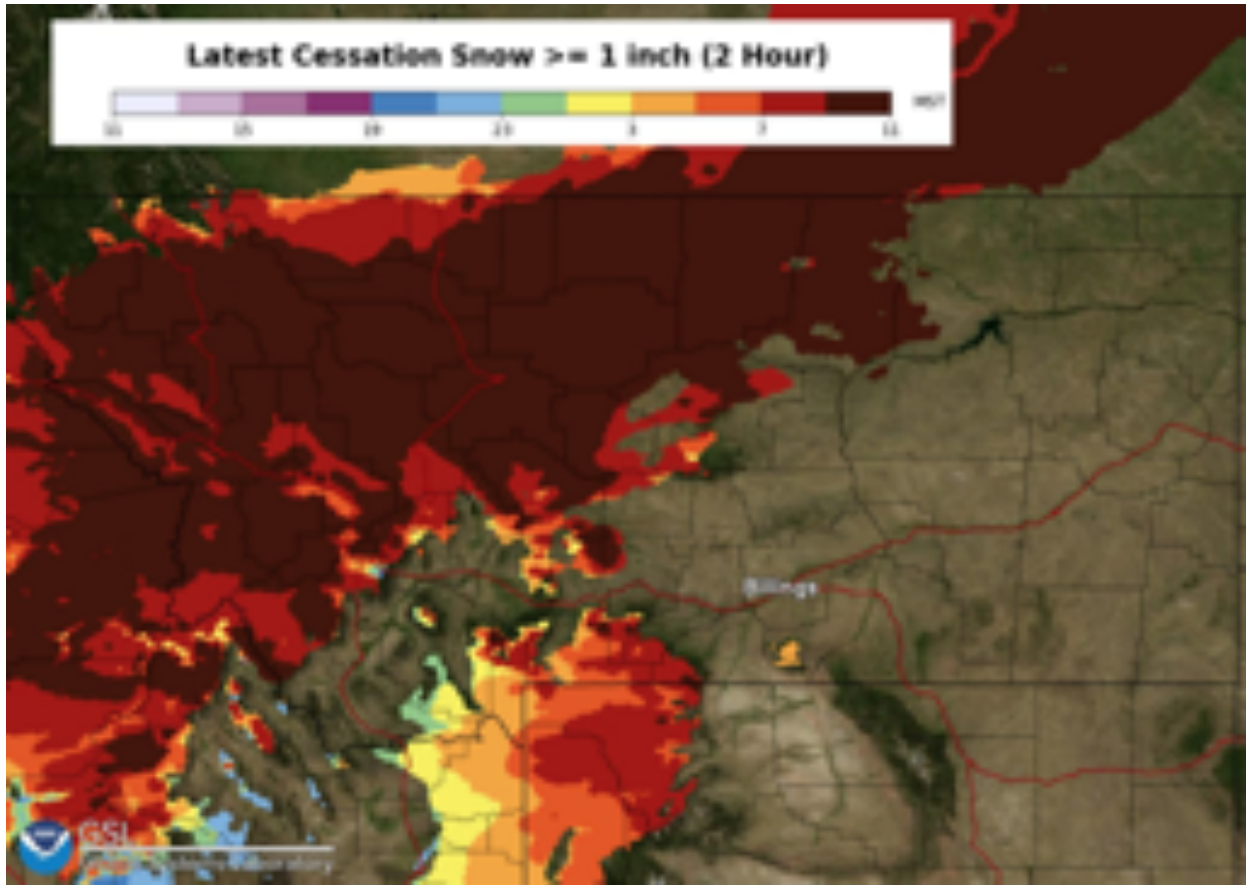
Regional DOT

Need for presentation changes

"I guess my **two low hanging fruits** would be, **#1, to not be 1-hour increments**, at least for public sharing or external sharing. And then, **#2, having the distinction between each of those bins be greater in color perspective**."

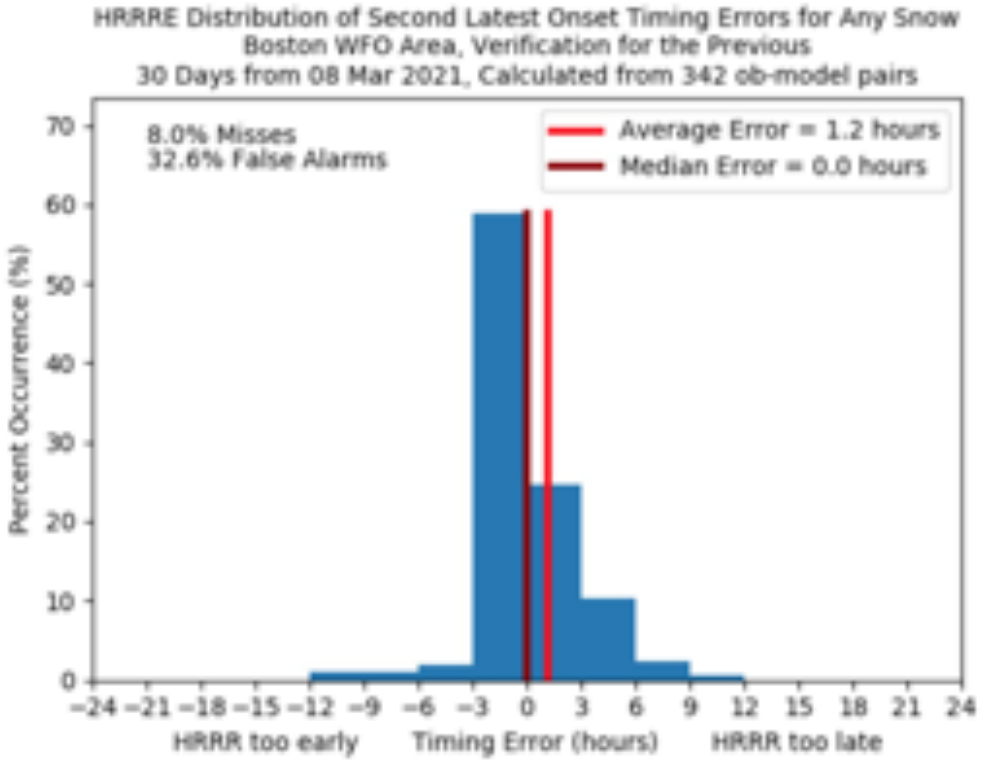
NWS forecaster #3

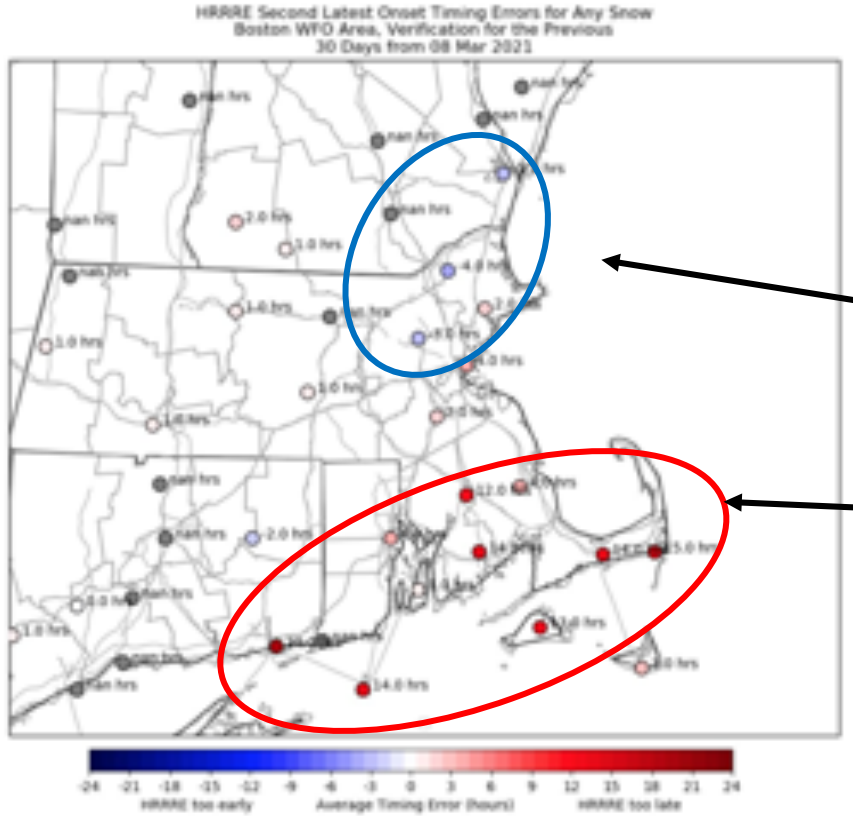
More interviews conducted by NCAR and GSL social scientists



Additional visualizations developed by GSL meteorologists and software engineers

Addition of Verification Information





All of the early timing errors were in northern MA and NH

All of the late timing errors were in southern MA and RI

Timing error is centered near zero, but we can use geographic verification information to adjust the forecast

We can use this knowledge of past model performance to nudge the forecast towards a better solution

Use in NWS Operations

Impressions	45,122
Total engagements	4,721
Media engagements	3,783
Detail expands	528
Profile clicks	310
Likes	58
Retweets	20
Link clicks	20
Replies	2

35,000+ views on Facebook (average is 10,000 views)

Future: pass along communication and visualization strategies to IDSS Engine project

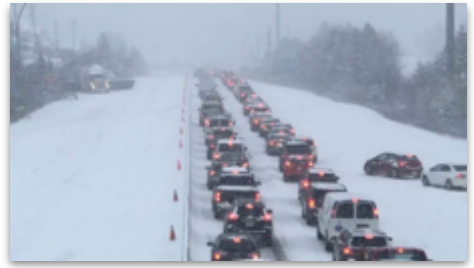
NOAA Global Systems Laboratory

IDSS Engine

Daniel Nietfeld
Liaison to the National Weather Service
Chief, Weather Information Systems Evolution Branch

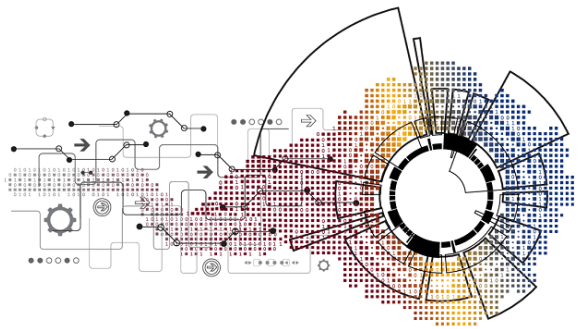
The IDSS Scenario

- It's 3 am at a National Weather Service Forecast Office
- High **impact** weather is moving into the area
- Core Partners of the WFO will want to know:
  - When do you think it will hit?
    - **How early** & **how late** could it start?
    - What's your **best guess** on when it might start?
  - **How much** do you think we'll get?
  - What's the **most** we could get?
  - How **certain** are you about these amounts, and the timing?

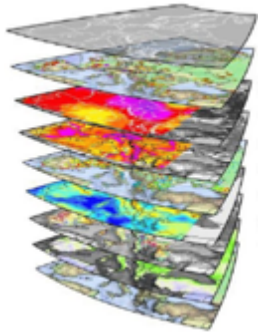


A Partner Needs Critical Information

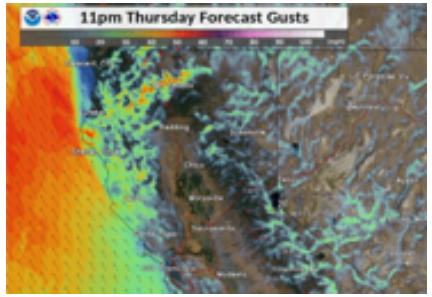
- "Risk Processors" run data mining **algorithms** to look through all of the observation and forecast information searching for matches to the criteria set by the partner
- If matches are found, graphics are generated in plain-language to illustrate the hazardous weather, and meta information about the hazard is created
- These graphics are bundled into briefing packages for distribution back to the Partner
- Sent to a Situational Awareness Display for Meteorologists to view and evaluate



Data mining algorithms



Identify matching weather criteria



Graphical / Text visualizations

EM / Partner

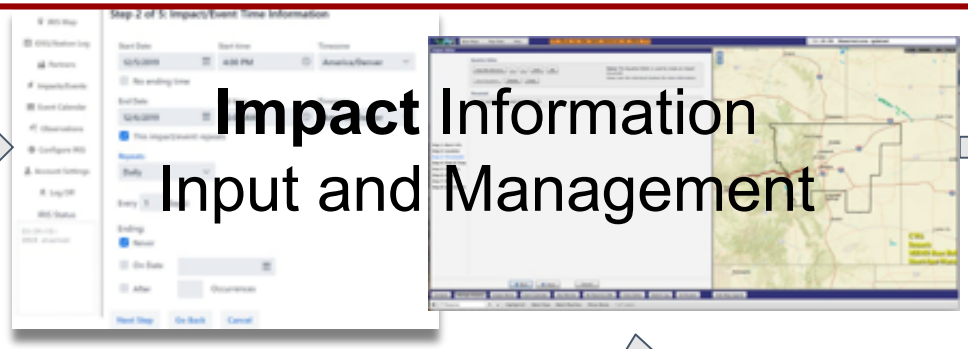
WFO/ ROC

Information Flow

Very Simplified Flow of the Processes

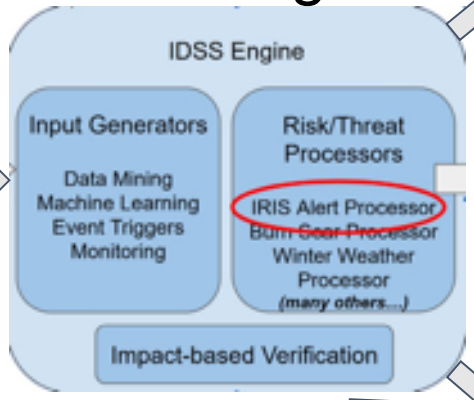
Core Partner

Contribution through Partnership with NWS Met.Dev Lab

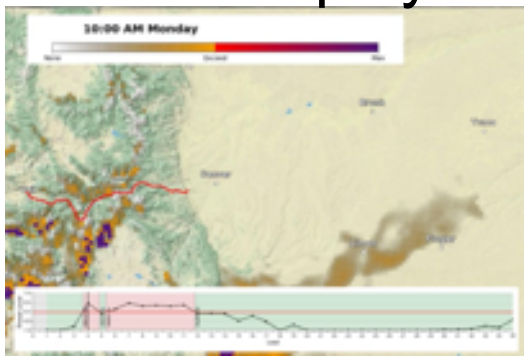


Impact Information Input and Management

IDSS Engine



WFO Displays



Briefing Package

Situation Awareness Display Prototype

Situation Awareness Display Prototype (Original)

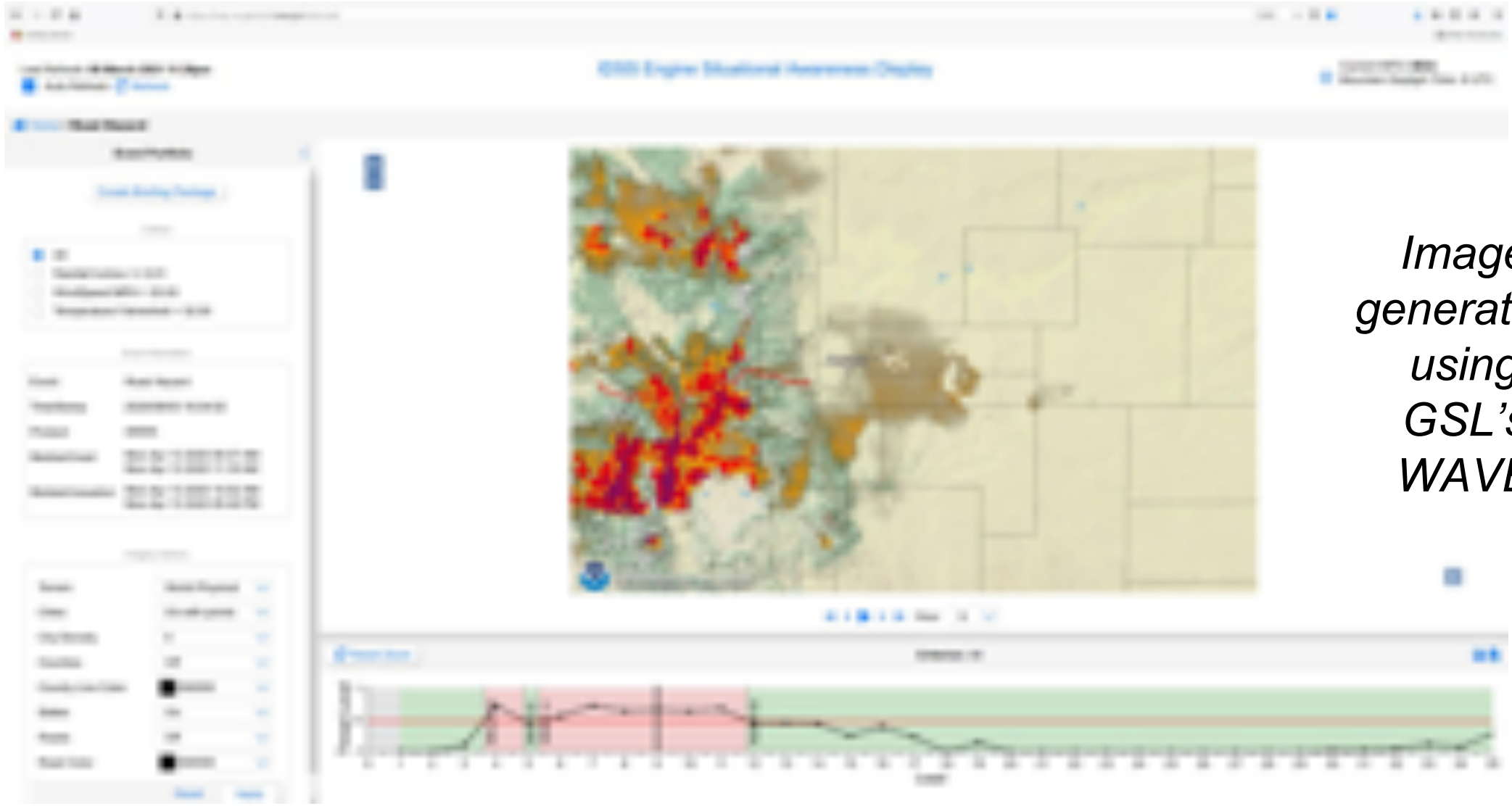
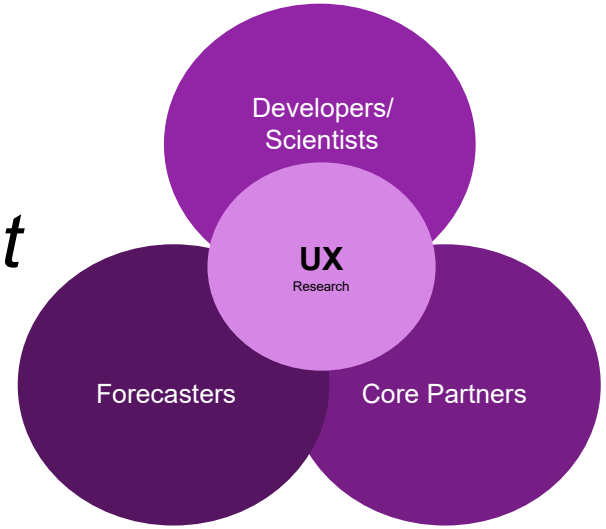


Image generation using GSL's WAVE

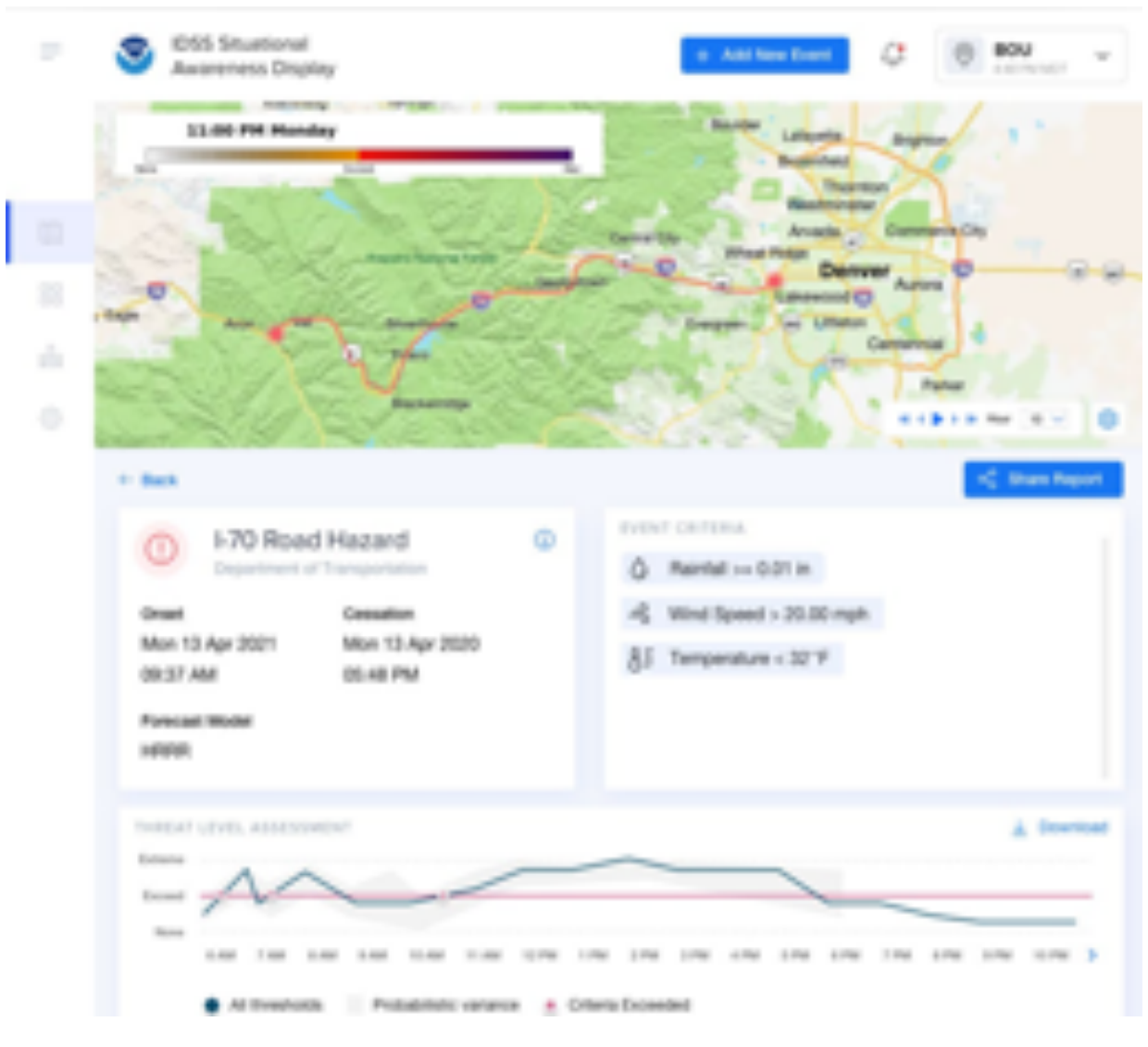
User Experience Research

- User Experience Researcher dedicated to IDSS Engine Project to bridge the developers with the users (forecasters and partners)

- *Newly hired UX Researcher to facilitate discussions*
- *UX in early and all phases of design and development*
- *Not an afterthought*



User Experience Design Improvements

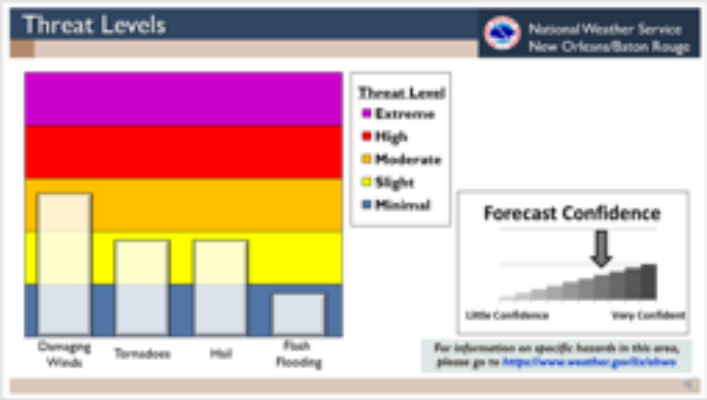


Partnerships

- NWS Science and Technology Integration Portfolio
  - Meteorological Development Lab
- NWS Analyze Forecast and Support Office
  - Decision Support Integration Branch
- OAR Weather Program Office
- OAR National Severe Storms Lab (MRMS for observations)

Future Work Planned

- **Verification information** will be utilized to quantify confidence and uncertainty
- **Fire Weather applications** and evaluations in proposed Fire Weather Testbed
- **Road Weather applications** in partnership with Department of Transportation
- Collaborate with NWS field representatives for **feedback and user engagement**



NOAA Global Systems Laboratory

Summary: Decision Support

Daniel Nietfeld
Liaison to the National Weather Service
Chief, Weather Information Systems Evolution Branch

Importance of GSL's Decision Support Activities

Decision Support is what gives **meaning** to forecasts.

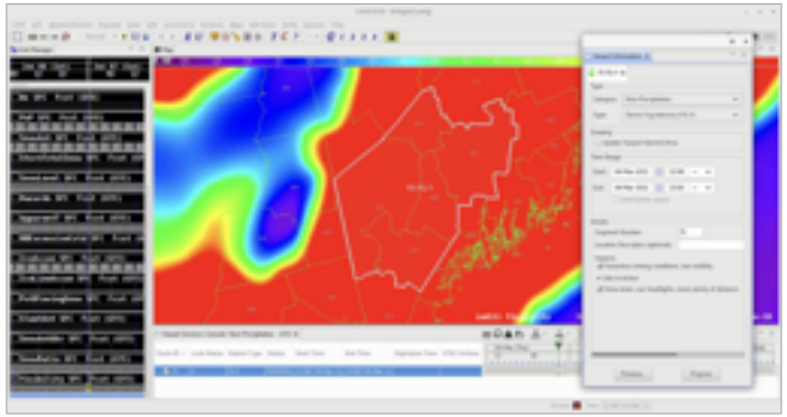
Forecasters "***connect forecasts and warnings to decisions made***," and they "***emphasize expert interpretation, consultation, and communication of forecasts and their impacts***"

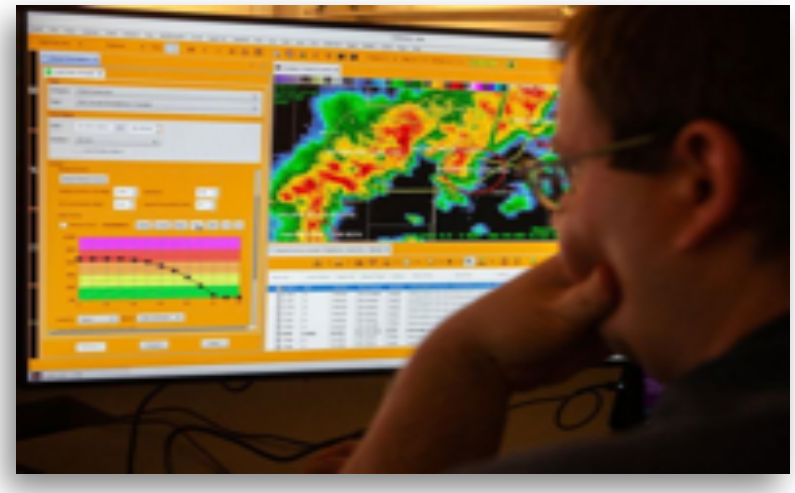
(NWS Strategic Plan 2019, Objectives 1.1 & 1.2, p. 7)



Revolutionizing Decision Support

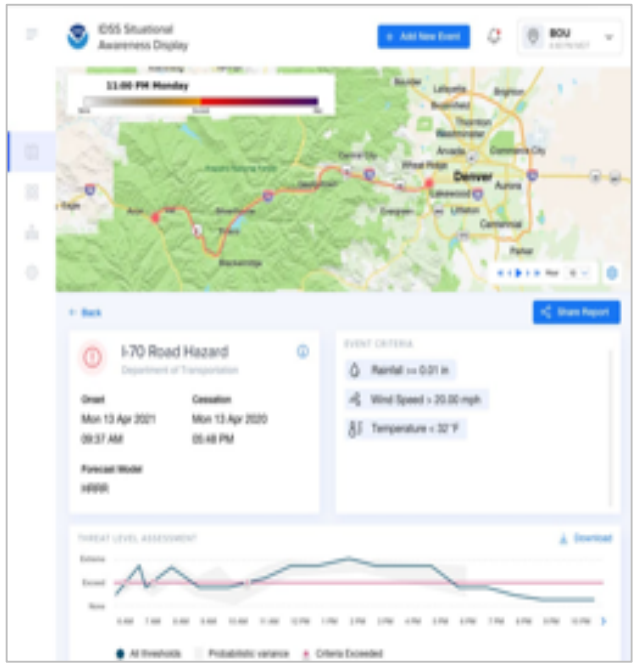
New Hazardous Weather Warning Tools





Decision Support Research

Delivering Information to Decision Makers with Cutting Edge Science and Technologies



Thank you!