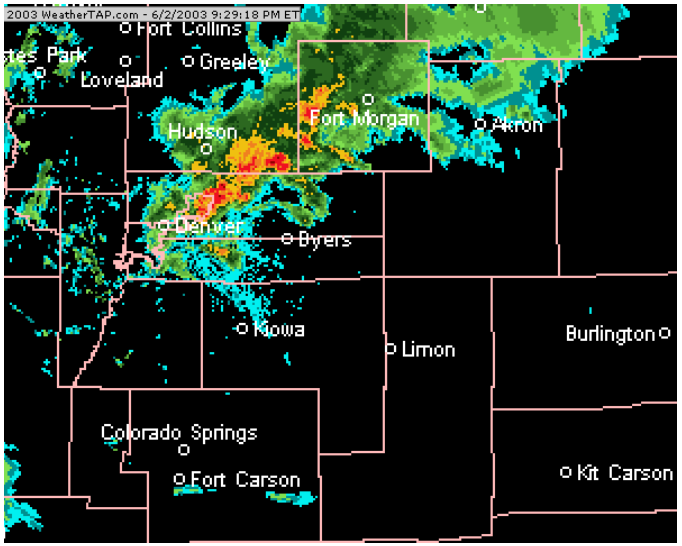


John F. Henz, Certified Consulting Meteorologist, CCM: jhenz@dewberry.com

Private Sector Meteorology: Using science to solve problems

Seminar, CSU Atmospheric Science Department: 300PM, January 28, 2013

John F. Henz: “my roots”

- BS, Meteorology, U. Wisc.-Madison
- 4 yrs USAF weather officer (1968-1971)
- MS, Atmospheric Science, Colorado State Uni. (1974)

President : GRD Weather Center
President – Henz Meteorological Services: **1975 - 2000**

- Firm purchased by HDR Engineering in Nov. 2000.

EMAIL: jhenz@dewberry.com

- HDR: 2000- 2010
  Atmospheric Science Practice Leader (2008-2010)
  Senior Professional Associate
  Senior Project Manager

  Dewberry Consultants: 2010-present
  - Senior Meteorologist
  - SME: Climate Change, Hydro-Meteorology

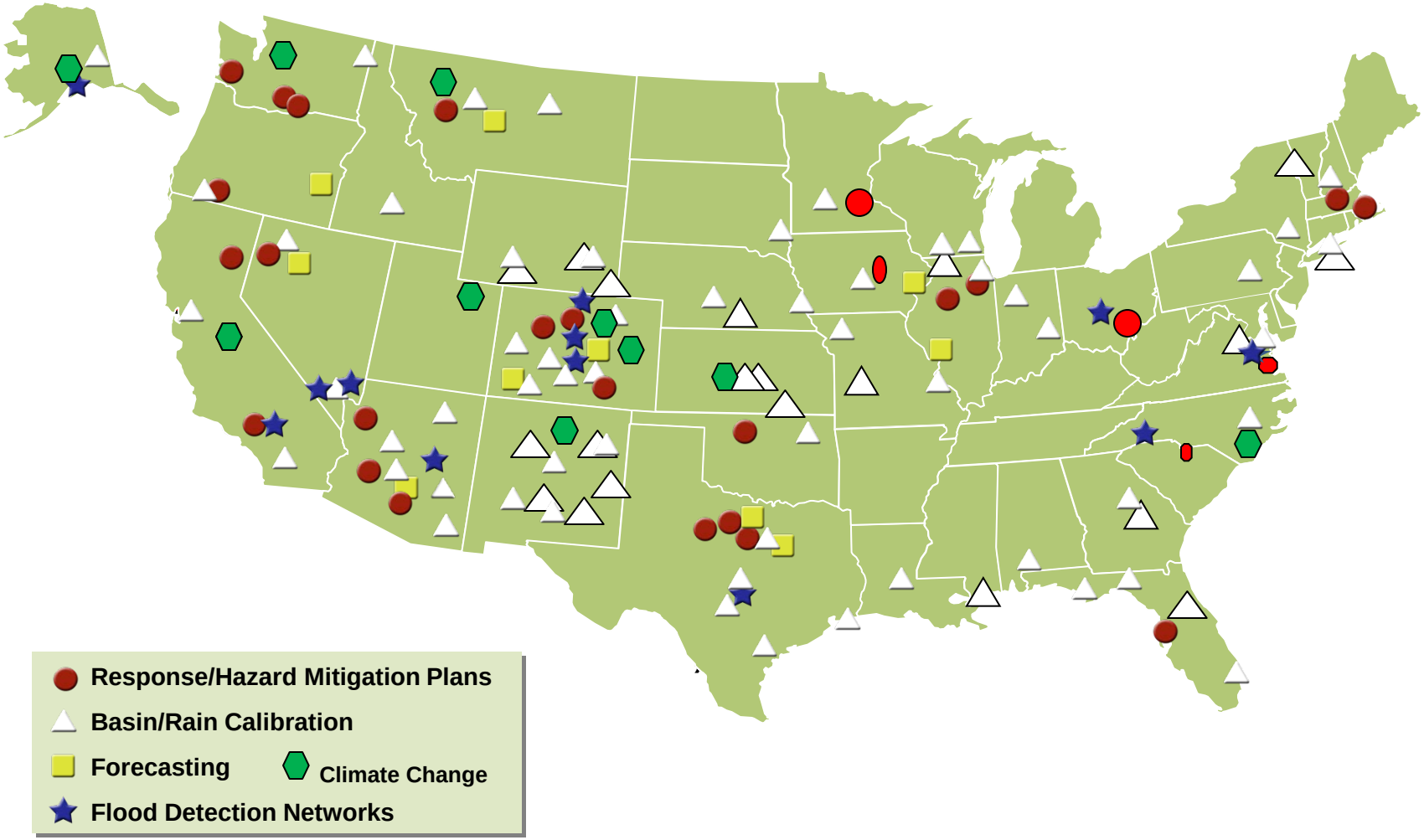
- American Meteorological Society

  Elected AMS Fellow 2013

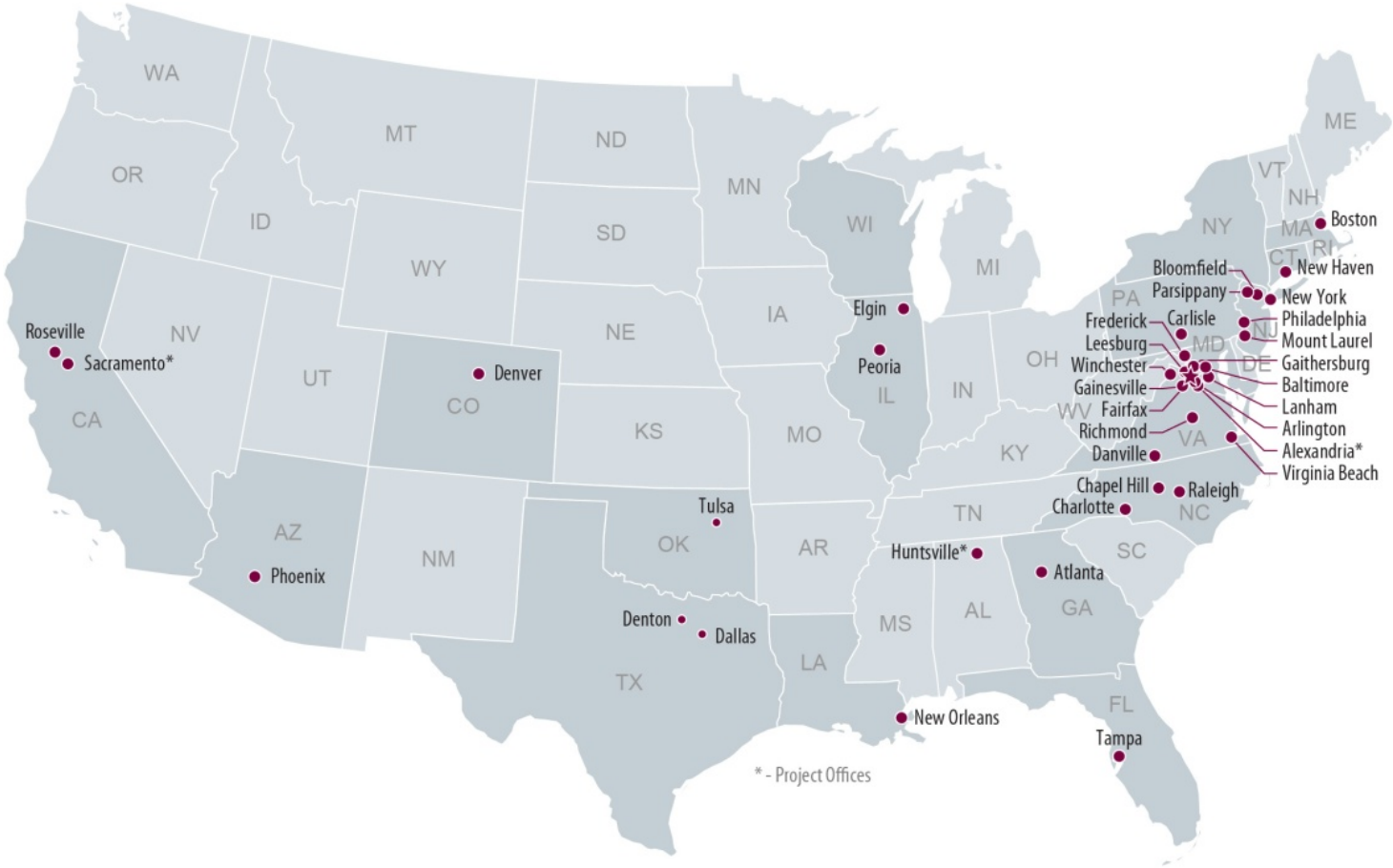
  Chair, Board of Certified Consulting Meteorologists 2010
  Member, 2007-2010
  CCM 1980 – present

  Board of Enterprise Economic Development , 2007-2009

Hydro-meteorological project experience 2000-2012 (HDR and Dewberry)



Dewberry is growing west



Dewberry

Our Team

John Henz, CCM
Senior Meteorologist

Stuart Geiger, CFM
Flood Risk Advisor

Robert Rahrs, GISP
Meteorologist

Mathew Mampara, PE, CFM
Senior Flood Risk Advisor

Ryan Towell
Meteorologist

Zack Roehr, CFM
Database Analyst

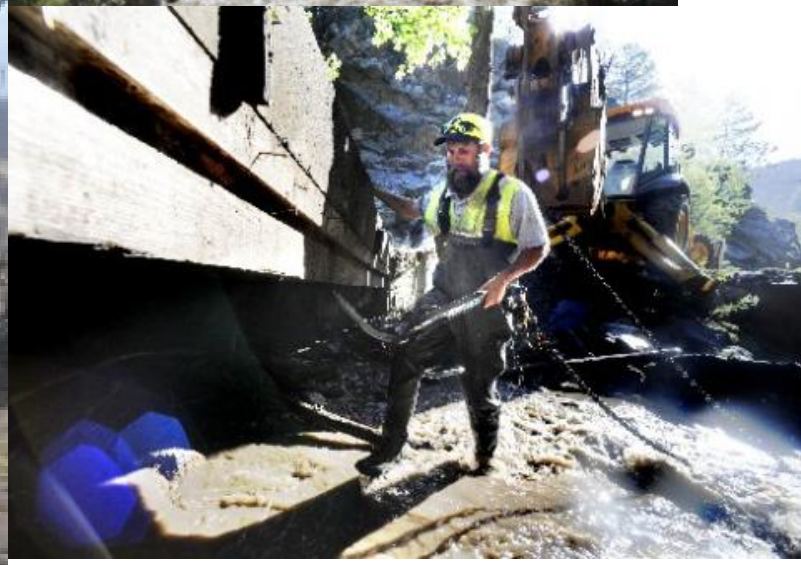
“Afternoon roadmap”

- Share some projects from 2011-2012
- Colorado Flood Threat Bulletin
- Climate Change and Water
- Platte River Restoration and Implementation Project Water Supply/Climate regime
- South Boulder Creek Design Storm/Floodplain
- Sea Level Rise

Colorado Flood Threat Bulletin

- Started in 2006 to provide detailed flood threat forecasts on a county level to EM's.
- Runs from May 1 to September 30.
- Issued once daily at 1100AM.
- Web-based forecast of snow-melt, river and flash flooding threat.
- Identifies the threat as None, Low, Moderate and High.

“Where will it flood?”



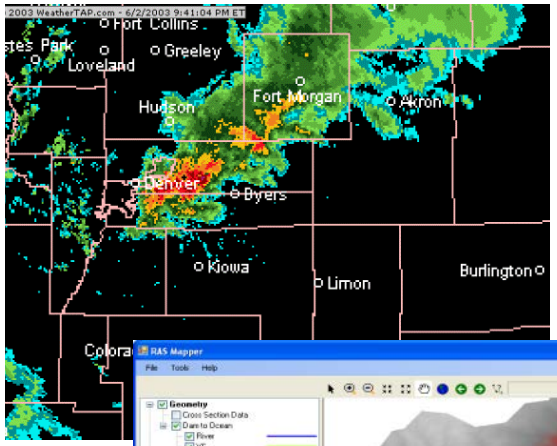
Debris Flows Close Roads In Fourmile Canyon

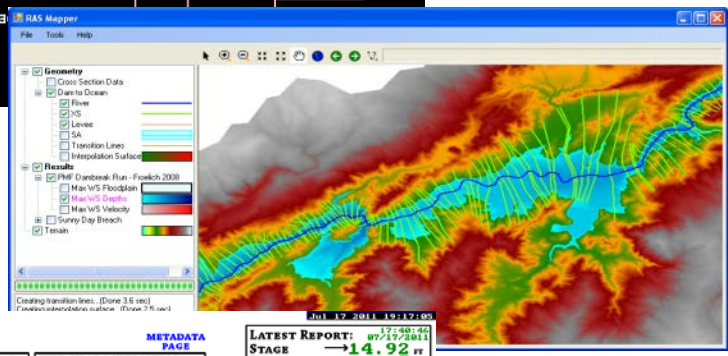
“Where will it flood?”

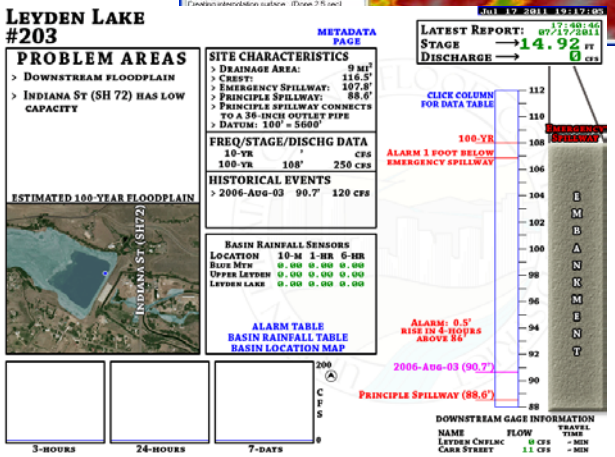
- Experienced analysis of threat
- Use of WRF-based regional models
- Linked to basin inundation studies and flood response plans
- Flexible support to emergency management
- Use of social media to link public

Site-specific EM Support

- Dewberry Denver and Fairfax Weather Centers are manned 24/7as needed.
- Skilled assistance for decision-making







- Critical facilities
- Evacuations
- Resource allocations

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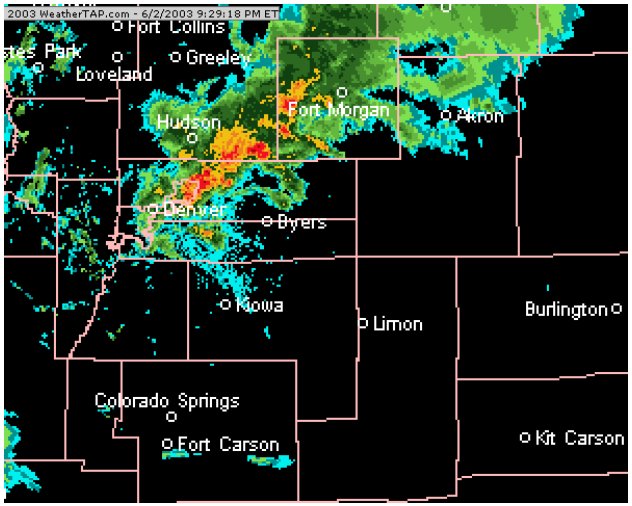
Communication Options

- Social media: Twitter, Facebook, RSS, YouTube
- SAMBA: Spatially Aware Message and Broadcasting Applications
- Mobile web pages; Android and iOS apps
- EMWIN – potential linkage
- Web Map Services (WMS, other open source file sharing protocols)
- TV/Radio media interfaces/file sharing

A Day in the Life of the FTB/FTO

www.coloradofloodthreat.com



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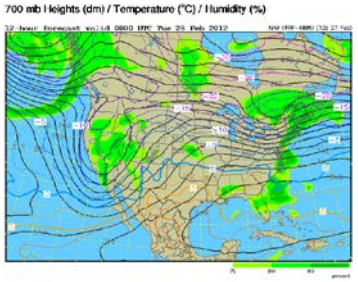
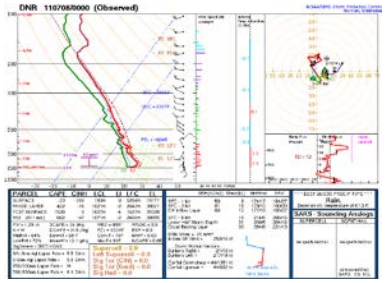
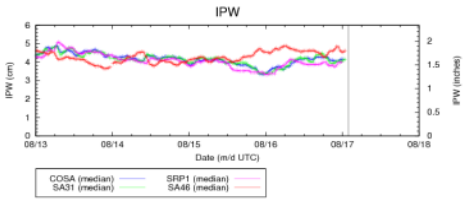
Observations



Surface Observations



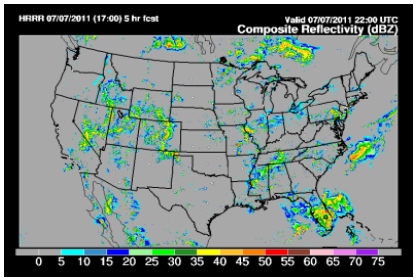
Soundings



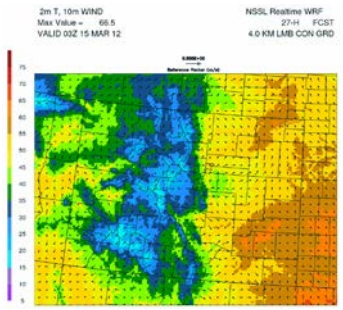
Atmospheric Moisture

+

Models



HRRR

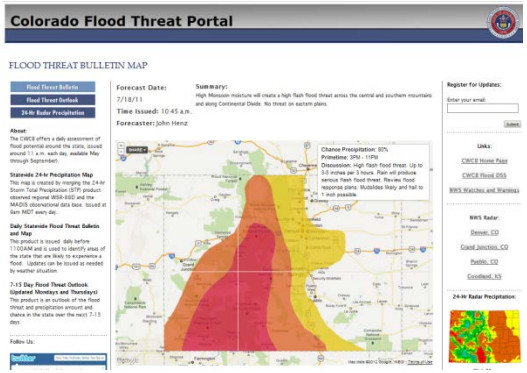


NSSL-WRF

WRF (U of A)

=

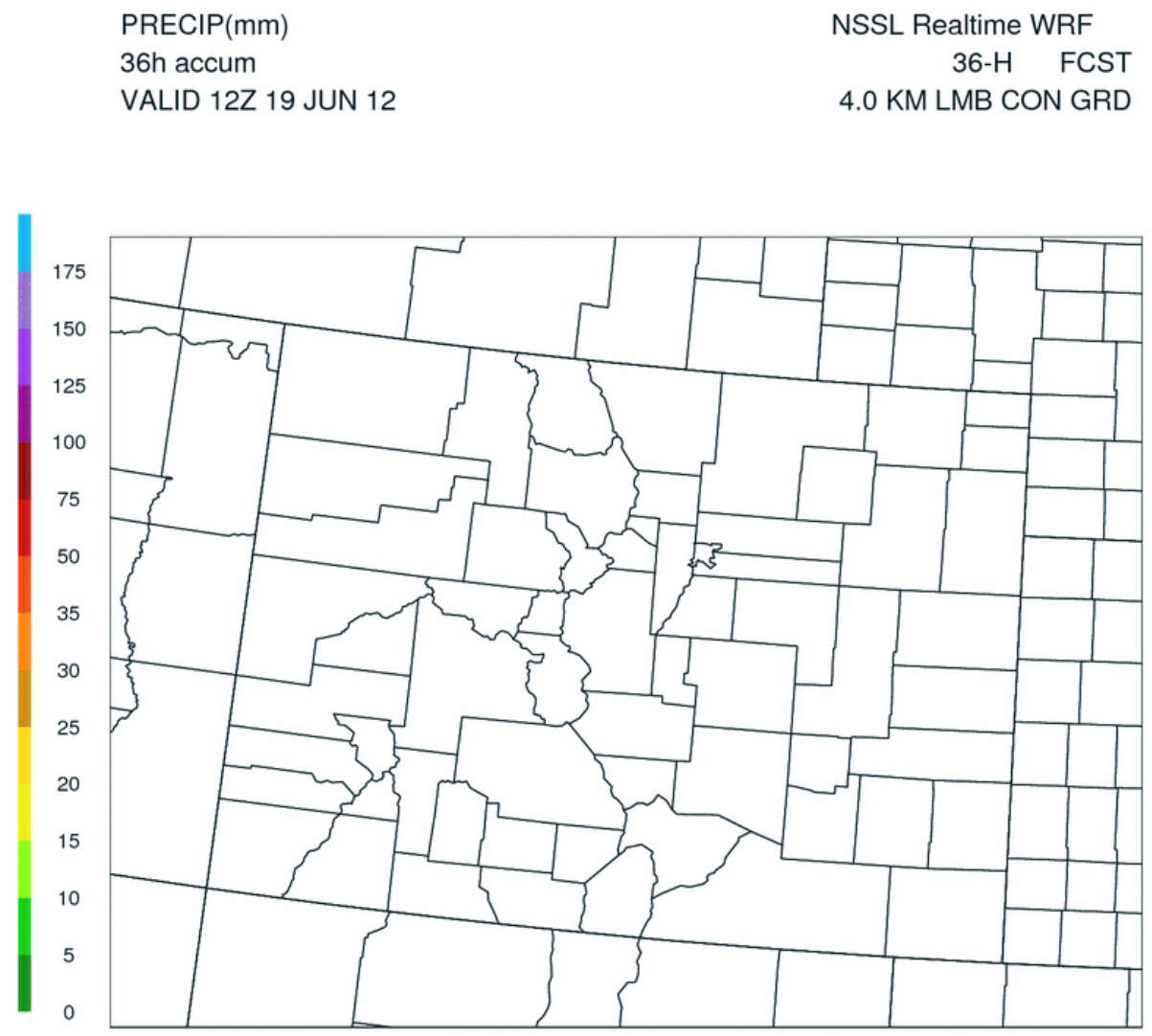
Colorado Flood Threat Bulletin



- Experienced analysts
- State of practice models
- Observation-based
- GIS-based for easy sharing

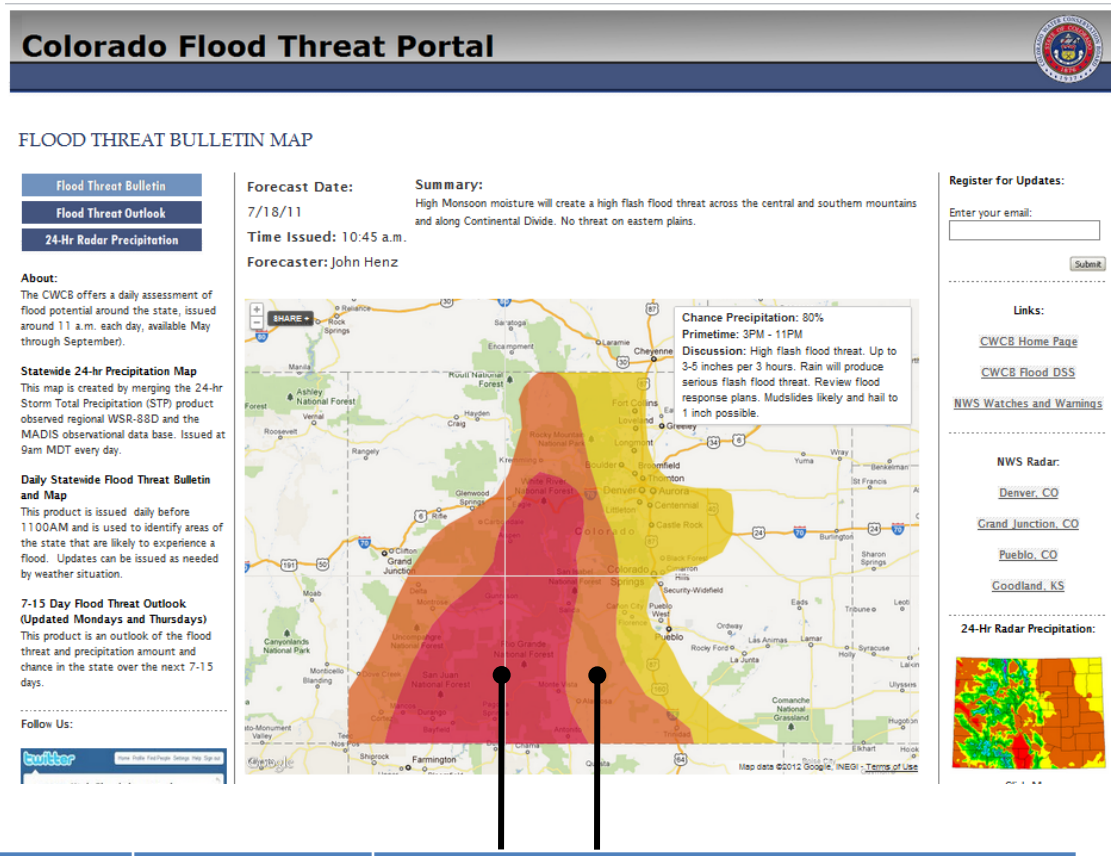
Dewberry Experience

Forecasts made on a county-specific basis for a 24-hour period



Flood Threat Bulletin

- County-specific forecasts of rainfall and flood threat
- Spatial threat identification
- Prime time for storms
- Storm movement
- Chance of flooding occurrence
- Web-based; PDF ready



Chance of Precip.	Prime Time	Discussion
80%	6PM – 11PM	High flash flood threat. Up to 3-5 inches per 3 hours. Rain will produce serious flash flood threat. Review flood response plans. Mudslides likely and hail to 1 inch possible.

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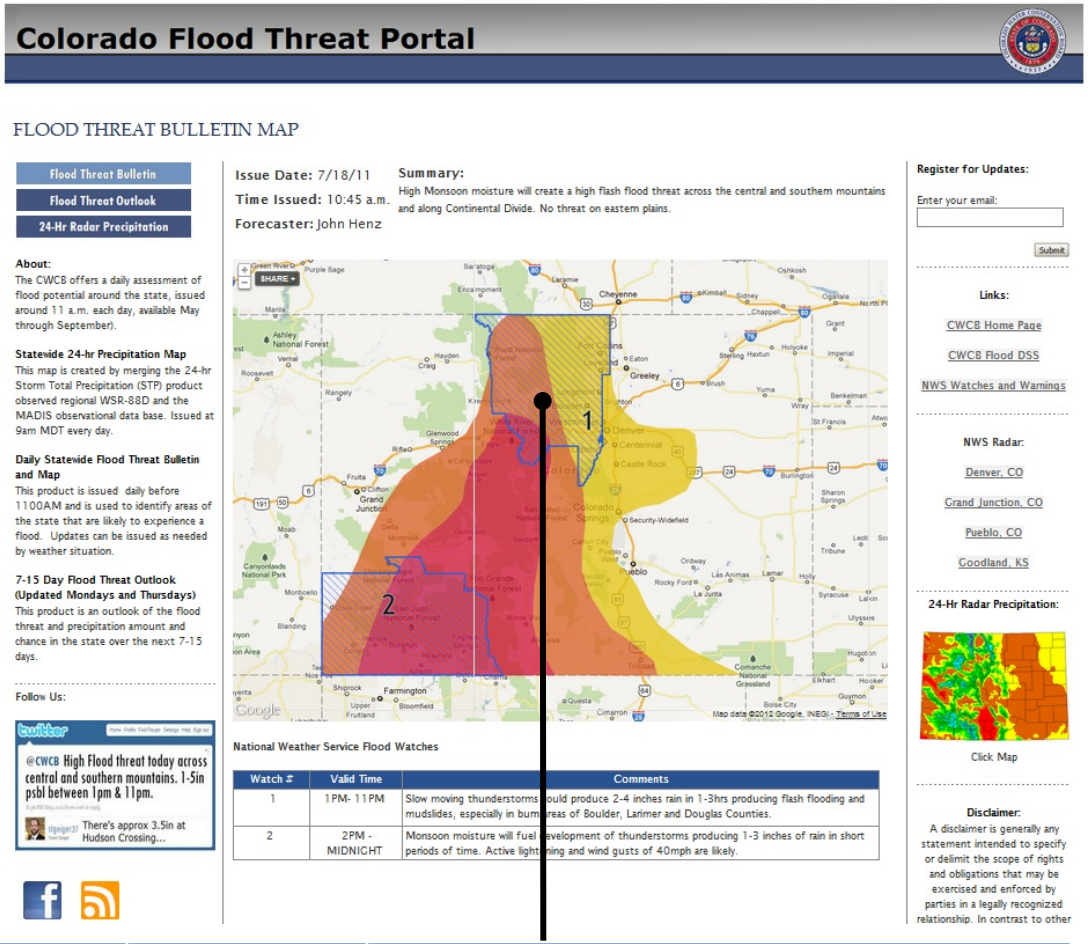
FTB: NWS Flood Watches

- Incorporation of NWS Web Map Services (WMS)
- Valid times of watches.
- NWS watch comments.
- WMS updated automatically



Watch #	Valid Time	Comments
1	1PM – 11PM	Slow moving thunderstorms could produce 2-4 inches rain in 1-3hrs producing flash flooding and mudslides, especially in burn areas of Boulder, Larimer and Douglas Counties.

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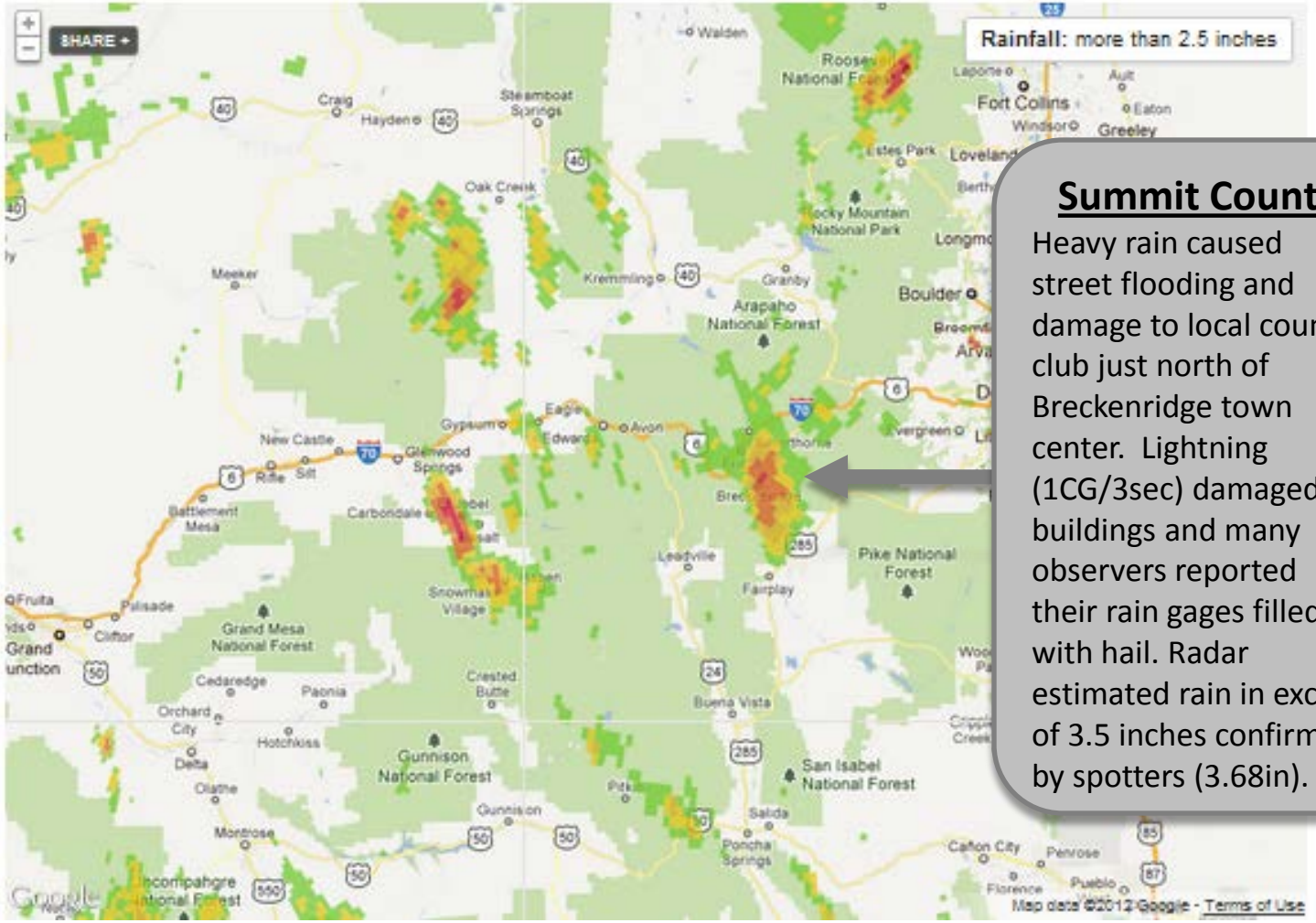

Storm Total Precipitation (STP)

Dewberry's Google-Earth based STP product merges observed National Weather Service WSR-88D Radar Storm Total Precipitation products from the Goodland KS, Front Range CO, Pueblo CO, Grand Junction CO and Cheyenne WY radars. Rainfall < 0.50 inch omitted. MADIS/CoCoRahs provides observed rainfall. Event summaries included. 3-5 day summed precipitation indicates where soil moisture content may be high enough to promote excessive runoff.

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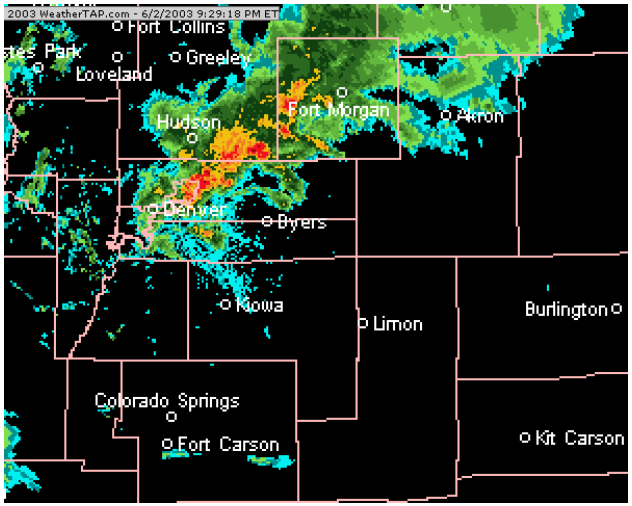
Flood Threat Outlooks



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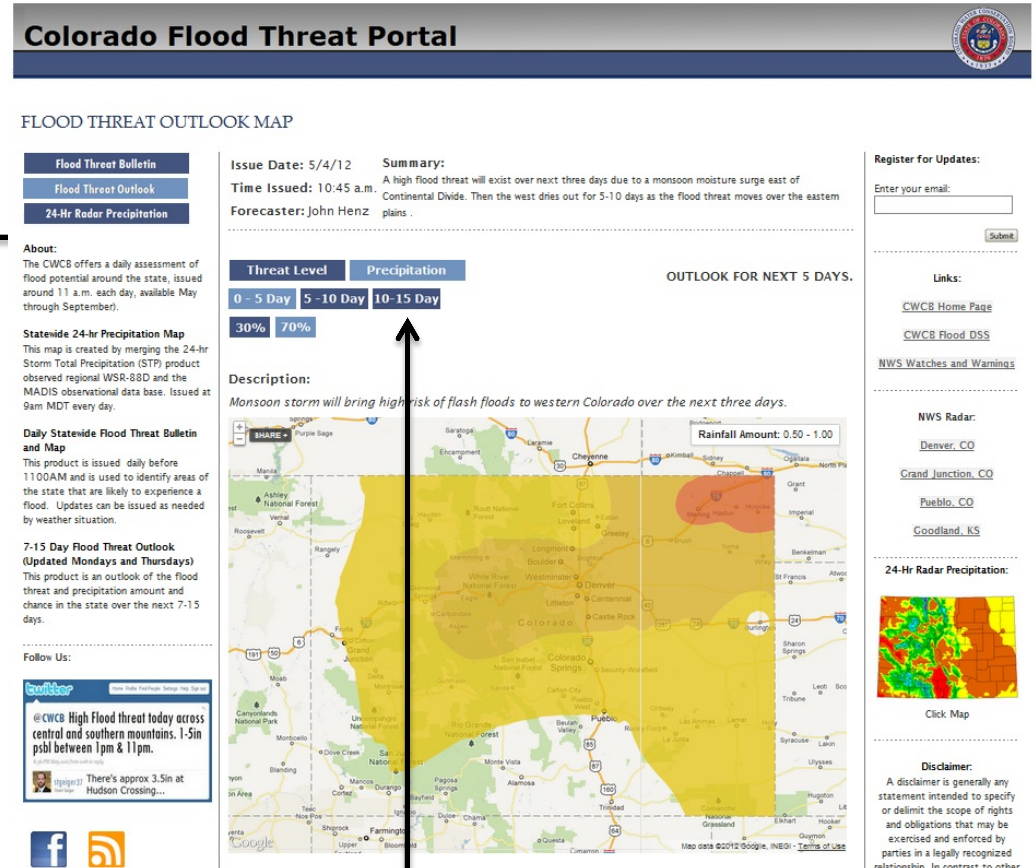
FTO: Enhanced Display

- Interactive navigation
- Categorical flood threat and precip. outlooks
- Valuable for planning by EMs and water supply interests
- Useful to agriculture and recreational groups



Toggle between threat and precipitation outlooks.

View estimated precipitation amounts for possible (30%) and likely (70%) chance.

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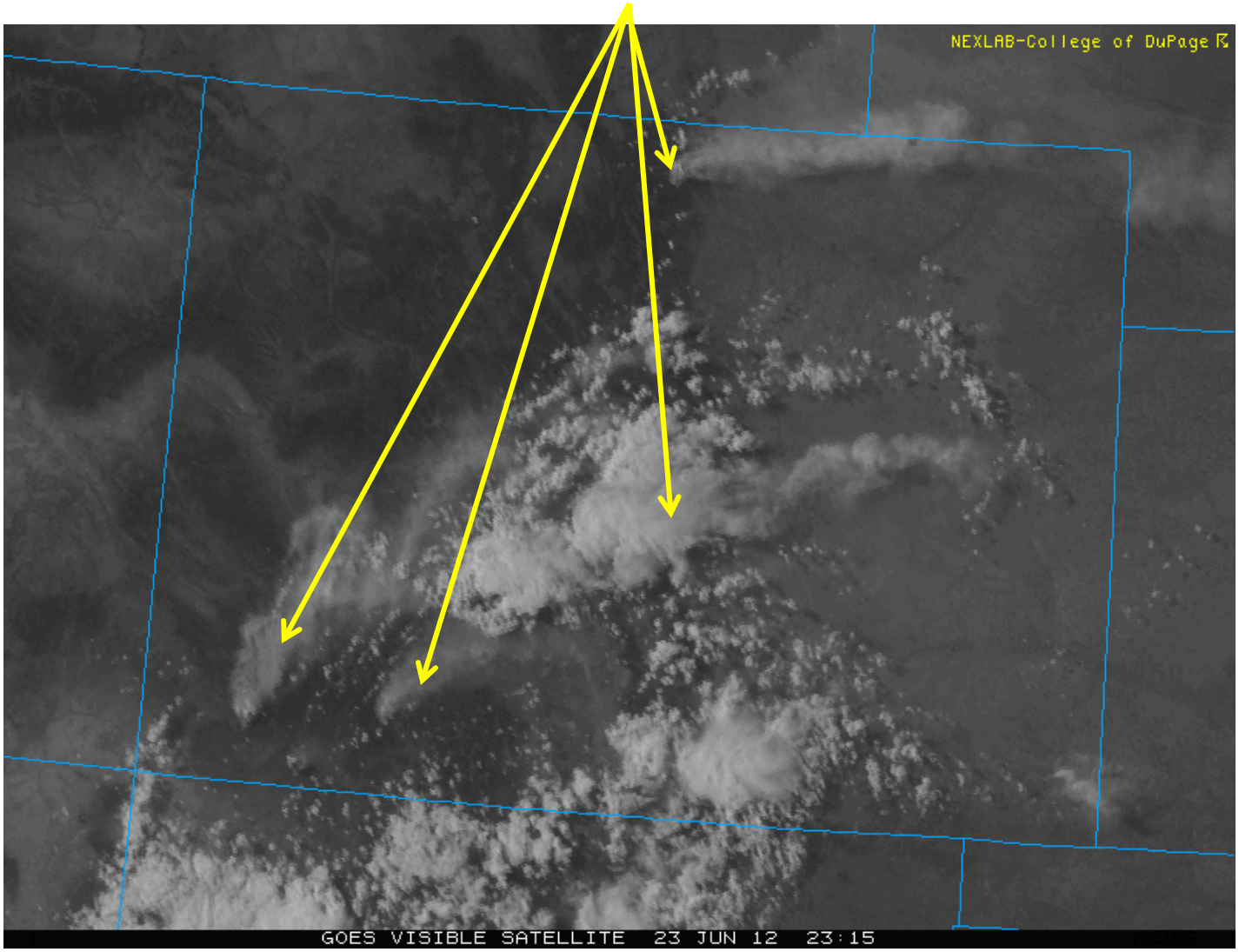
Added complexity: Over a dozen recent fire burn scars = very flashy flood/mudslide issues



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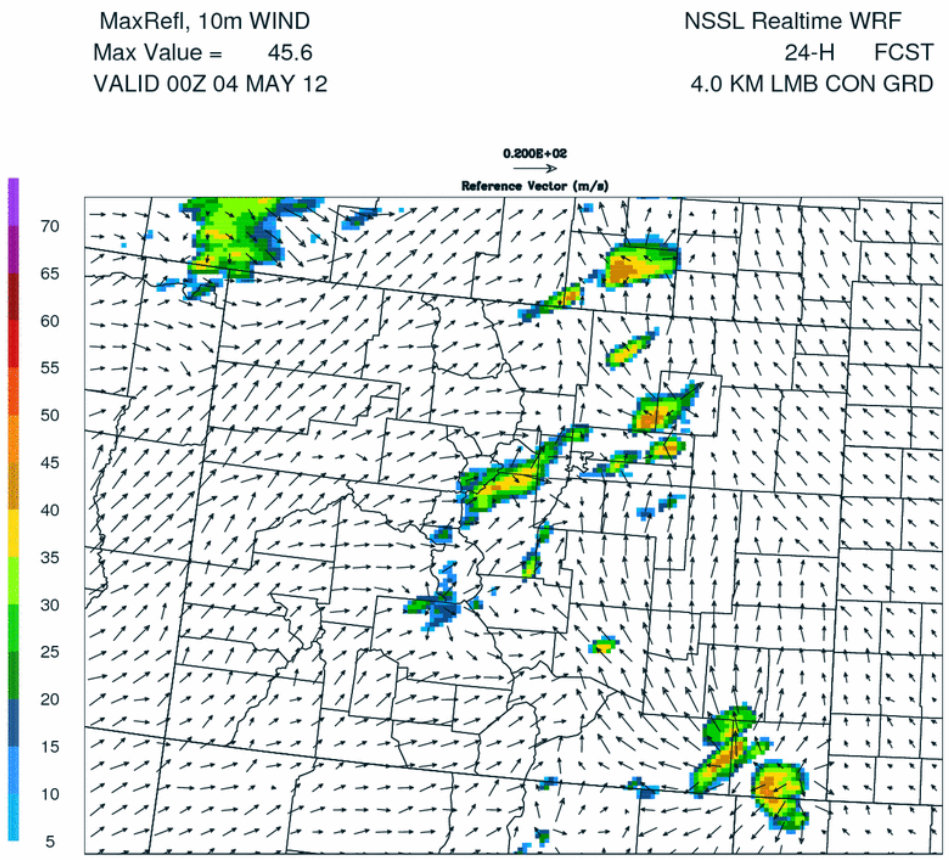
Experience with NSSL-WRF

Provide operational meteorologist guidance for a remote and a "rusty" meteorologist. No connections to NSSL community.

NSSL WRF specs: http://www.nssl.noaa.gov/wrf/

- **The WRF model (v3.1.1) configuration includes:**
- **MYJ BL/turbulence parameterization**
- **WSM6 microphysics**
- **RRTM long wave radiation Dudhia short wave radiation**
- **Noah land-surface model**
- **Positive definite advection of moisture 4 km grid length (1200x800)**
- **35 vertical levels**
- **Time step 24s**
- **Run once daily at 00Z for 36 hours at NSSL; available on Web.**



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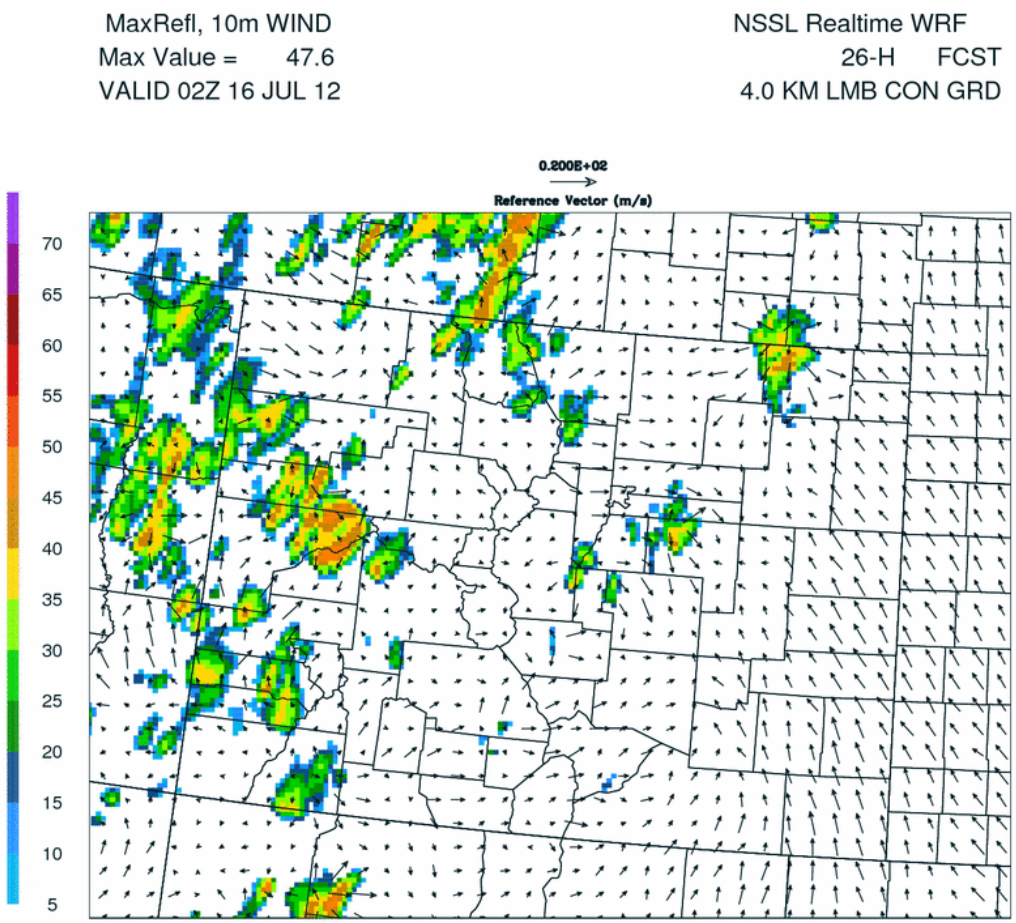
Meteorologist concerns and NSSL-WRF products

- One out-of-state meteorologist, 20yrs experience all on East Coast.
- One meteorologist with 14 yrs experience but last flash flood prediction 3 yrs ago.
- Experienced 40-yr+ meteorologist
- Needed tool to assist the “rusty” and the out-of-state meteorologists in predicting the flash flood threat.
- NSSL-WRF “PUB slice” provided forecasts of upper air, surface fields, soundings, hourly radar reflectivity and rainfall, 36-hr rainfall and lightning.
- Fine scale grid with pbl winds.
- All forecasters liked products and format.



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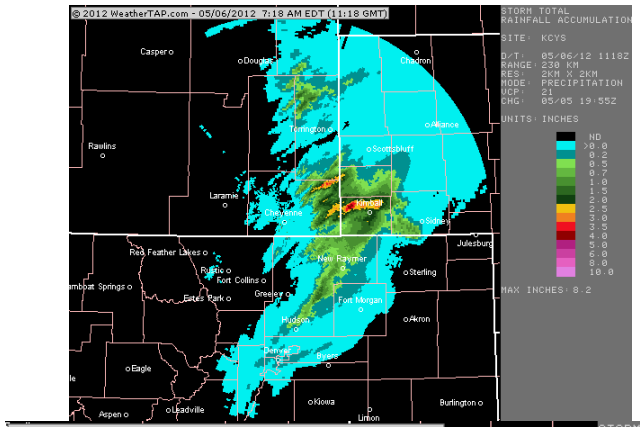
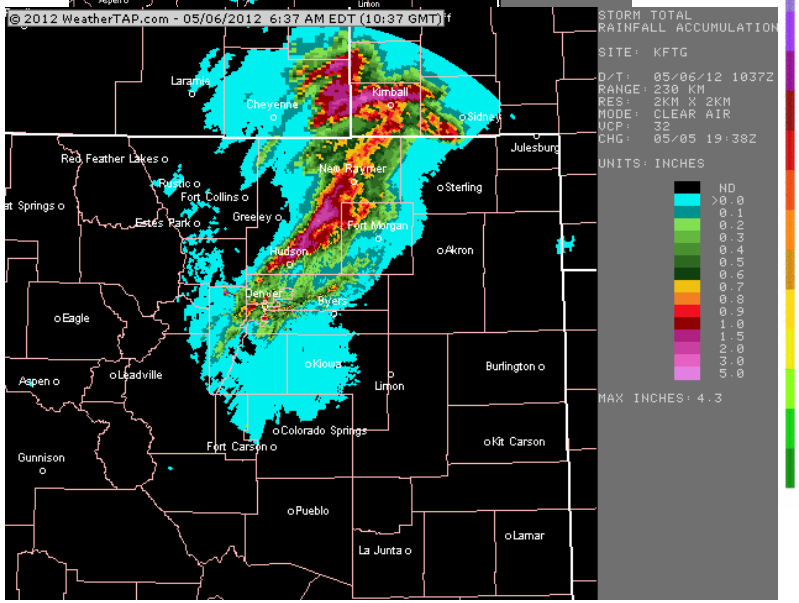
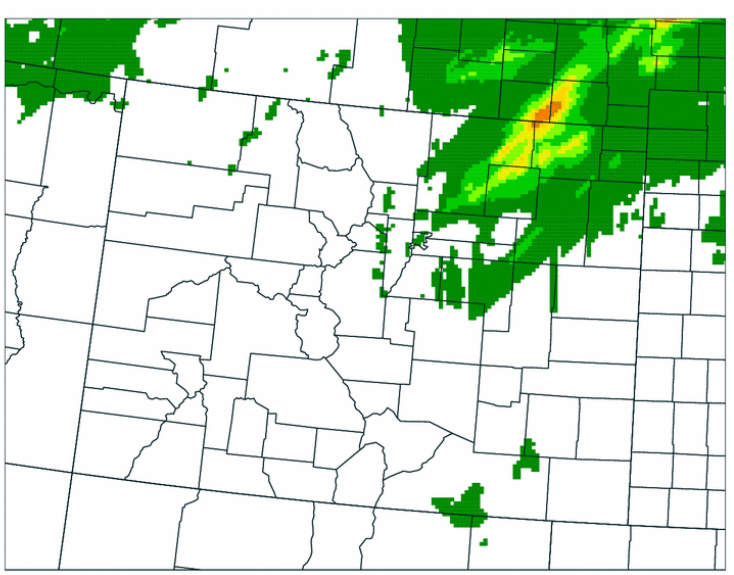
May 5, 2012: first indication WRF could help



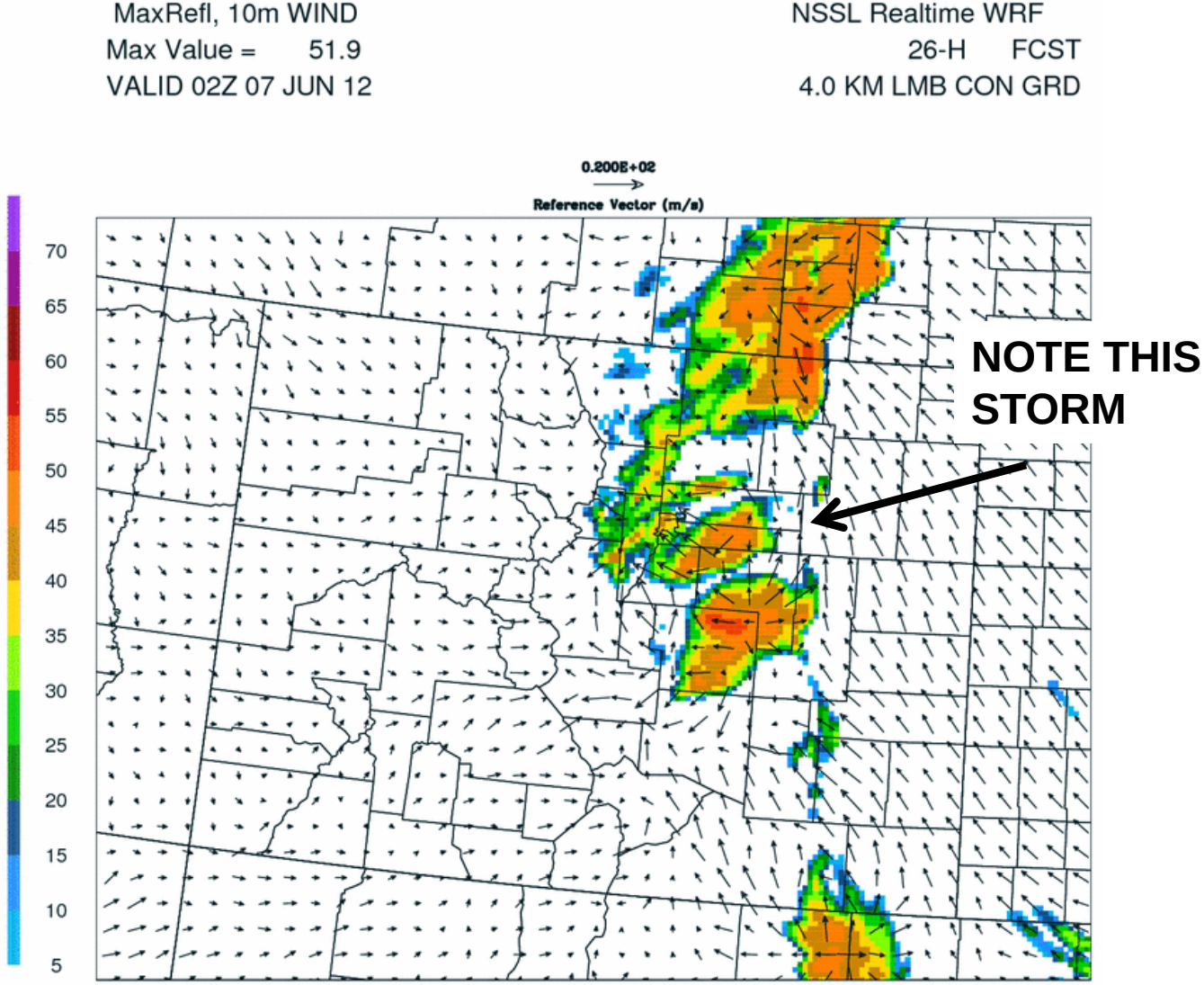




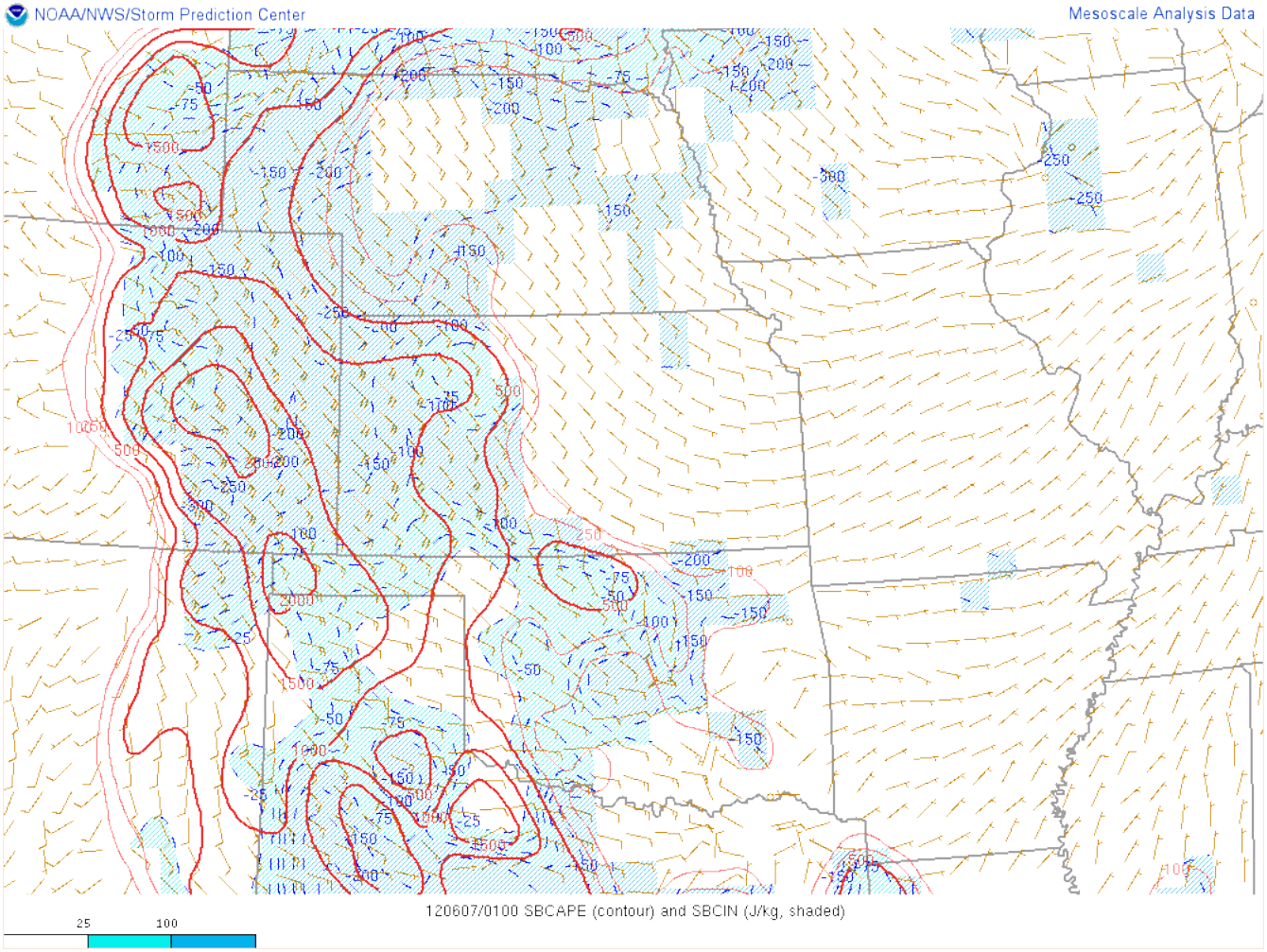
Two FTB project examples

- June 6, 2012 Douglas County south of Denver CO: 4-6in/3hrs rain and flood
- High Park Fire Burn area west of Fort Collins CO: Numerous mudslides in 1-2in/1hrs rainfall

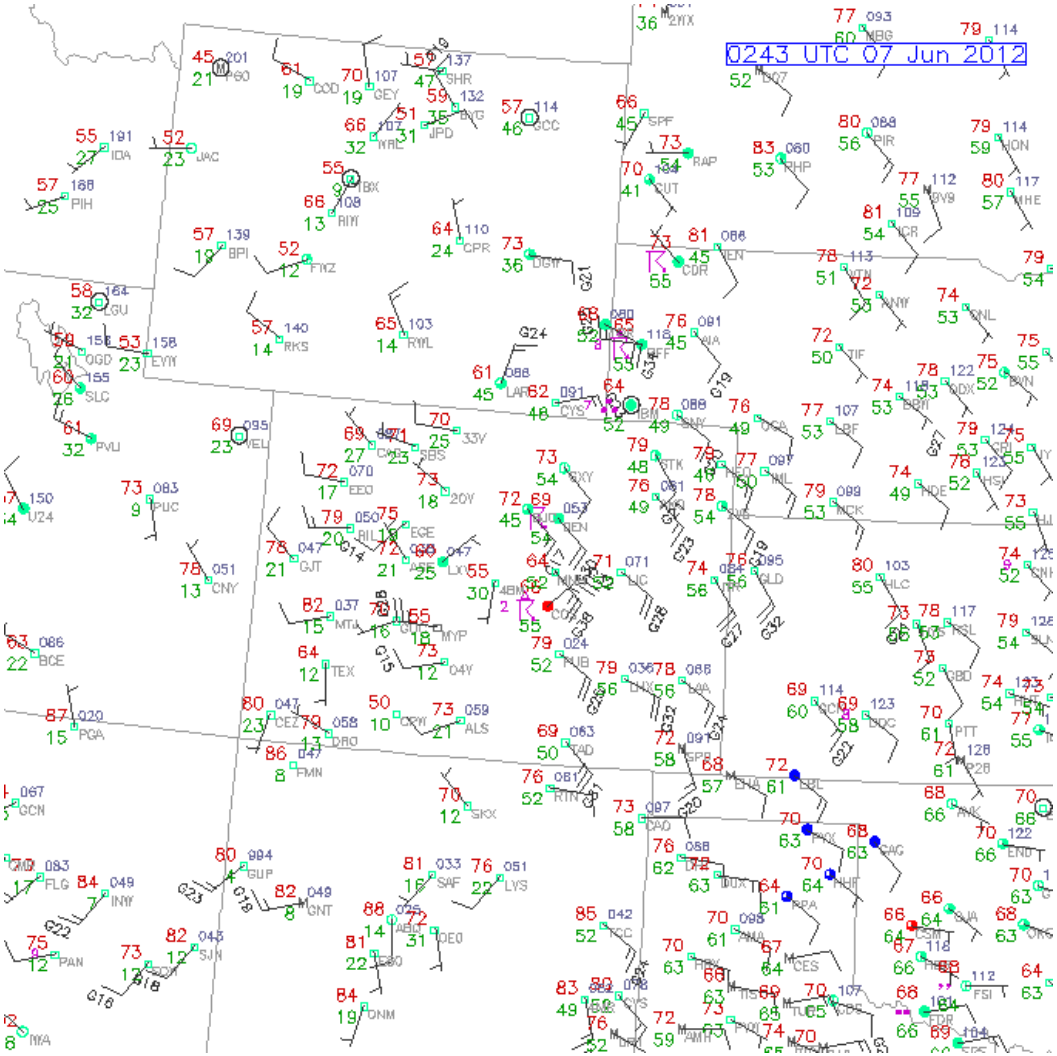
Forecast radar reflectivity



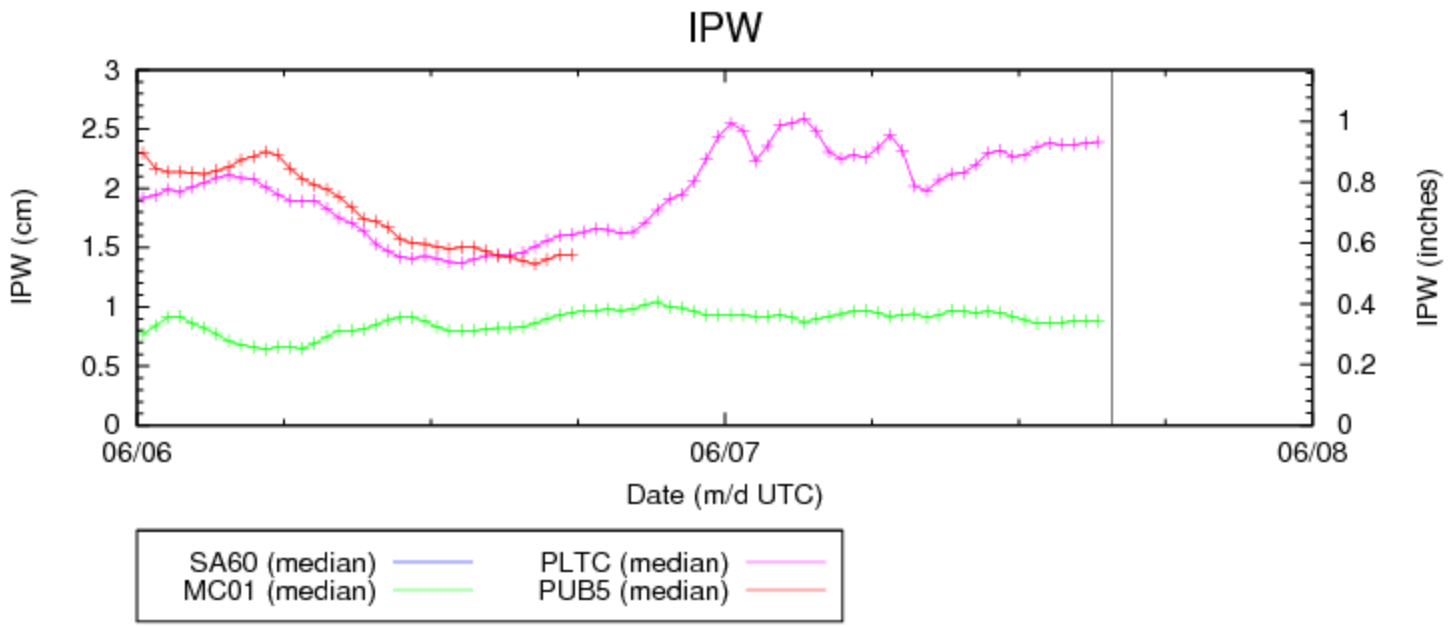
PM SPC CAPE analysis



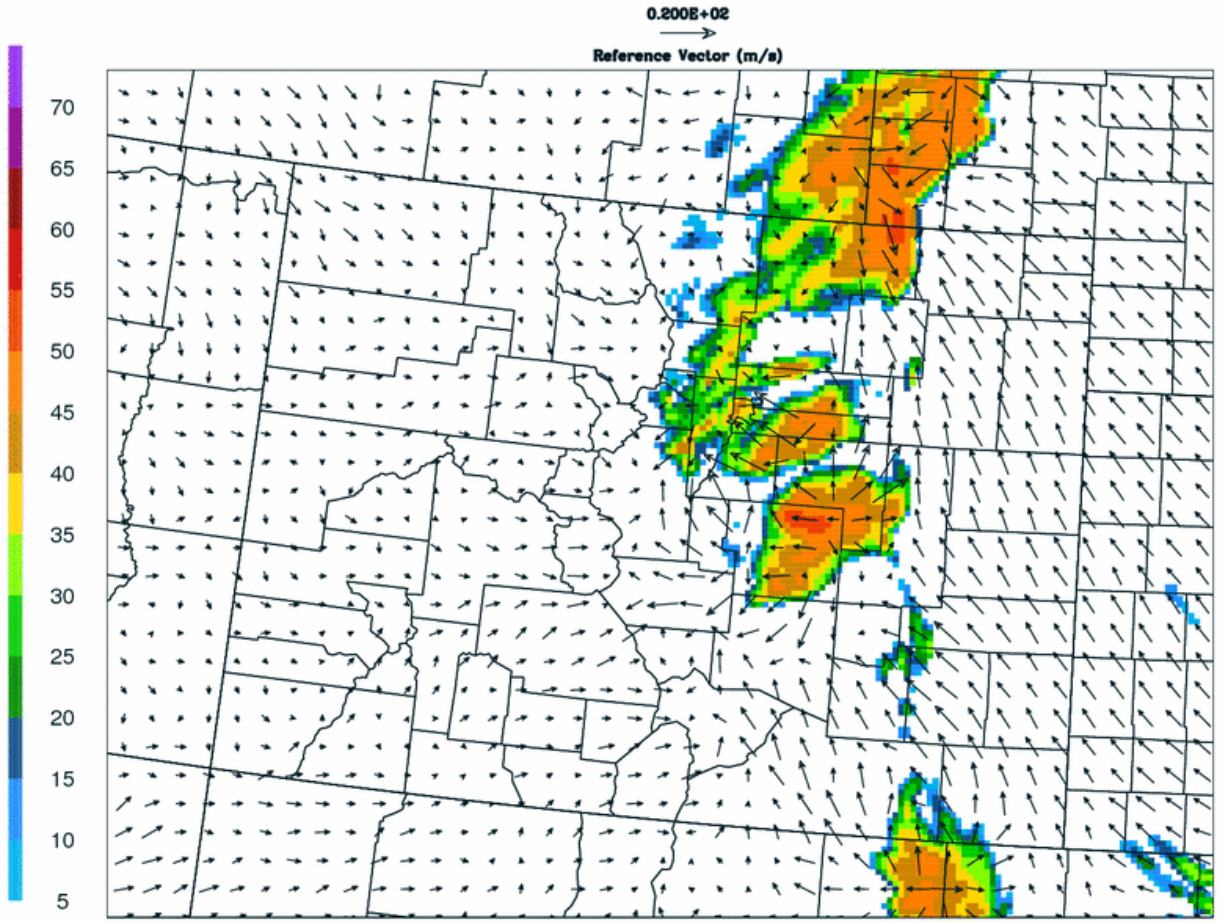
June 6, 2012 Colorado Surface conditions



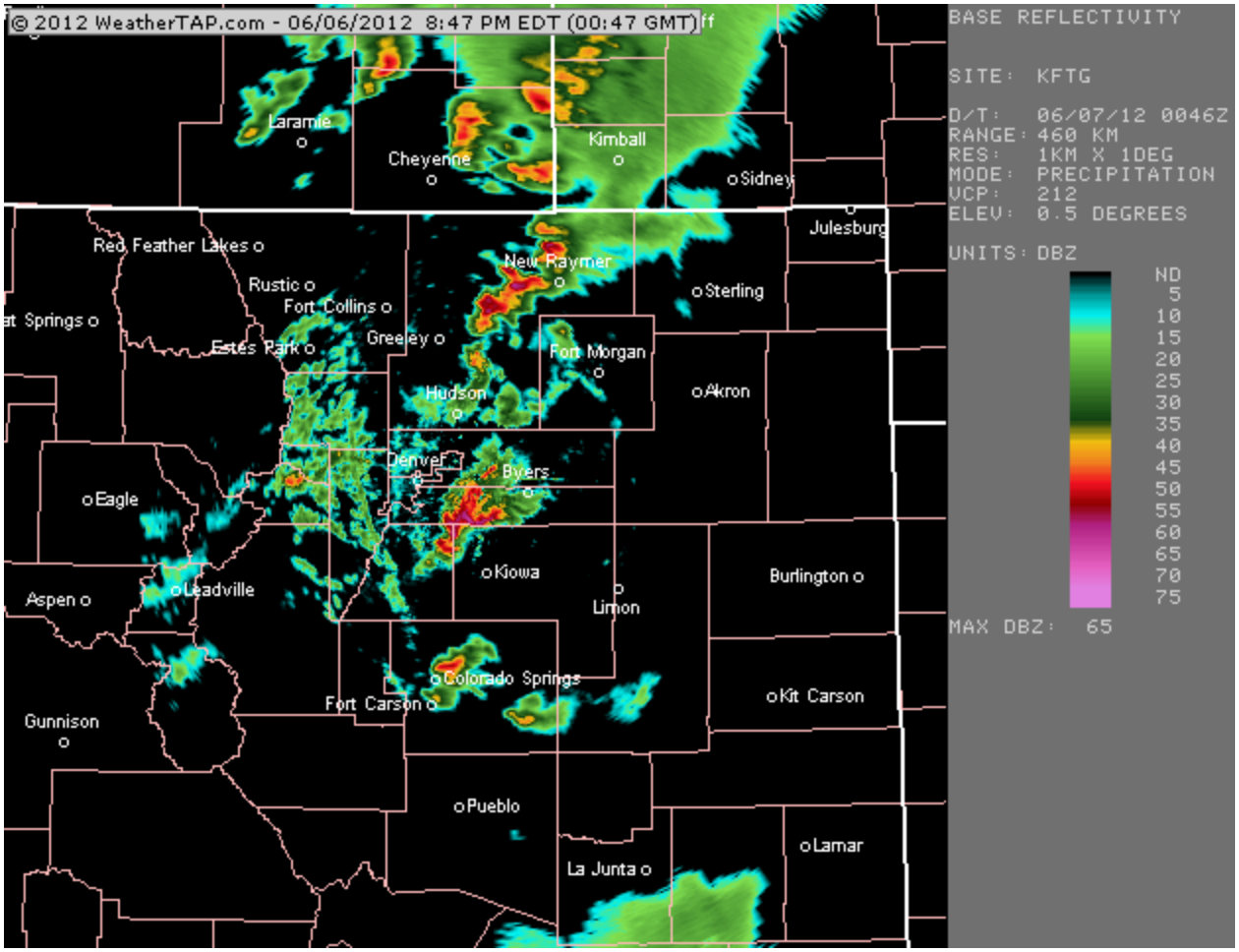
Rapid increase in IPW as LLJ imports low level water by 00Z



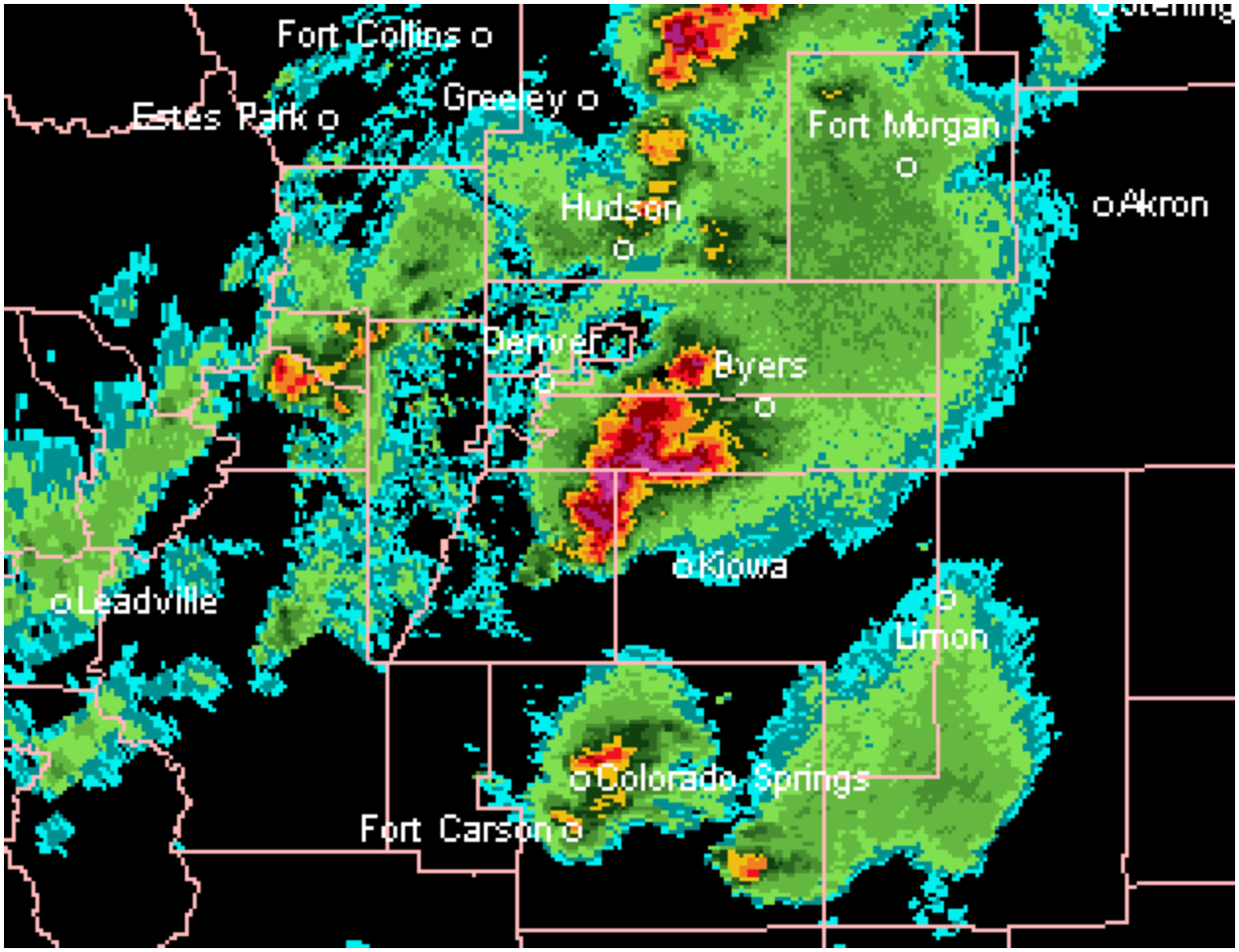
Forecast radar reflectivity



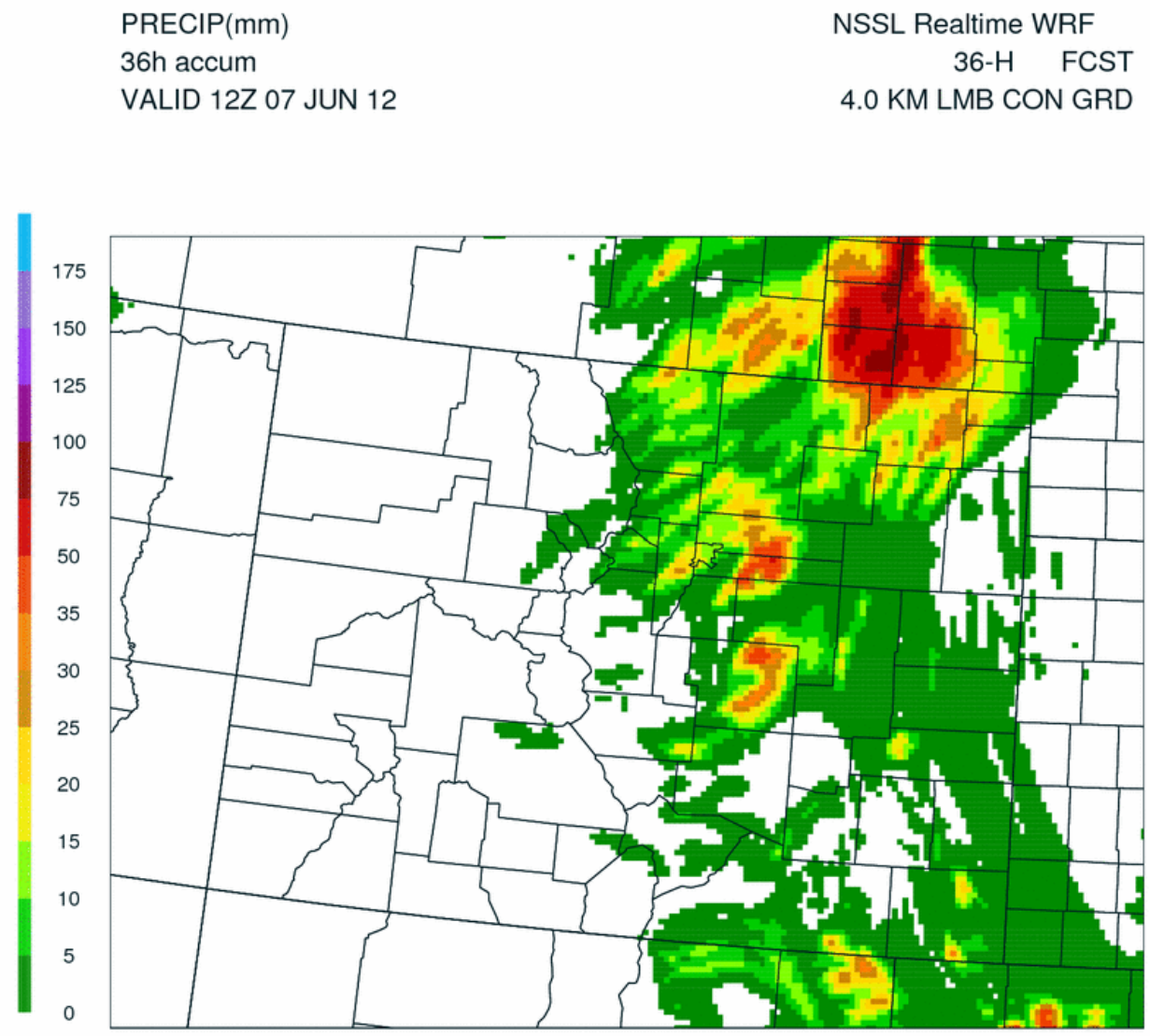
NSSL WRF “hit it”



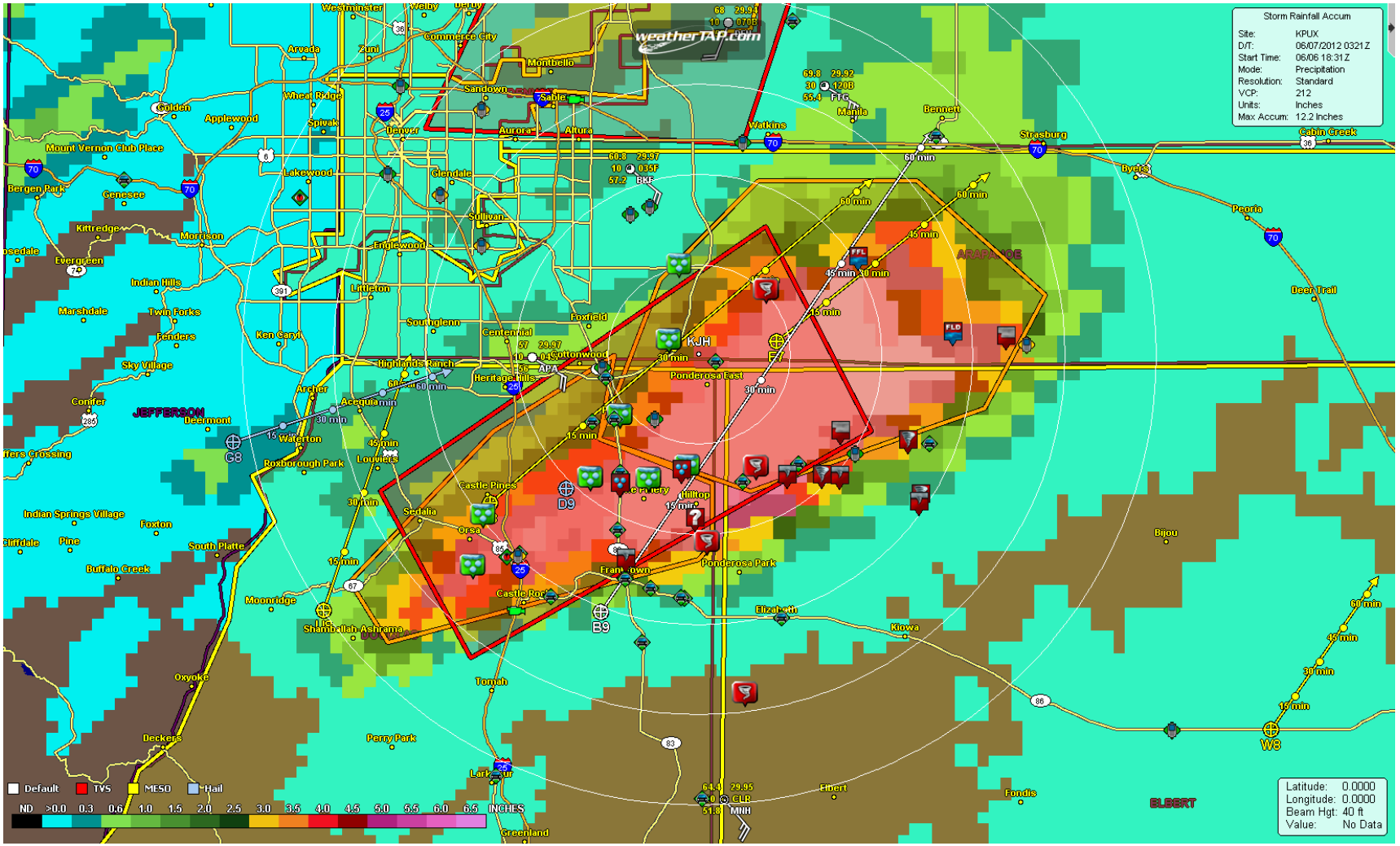
Thunderstorm occurs where its predicted to be

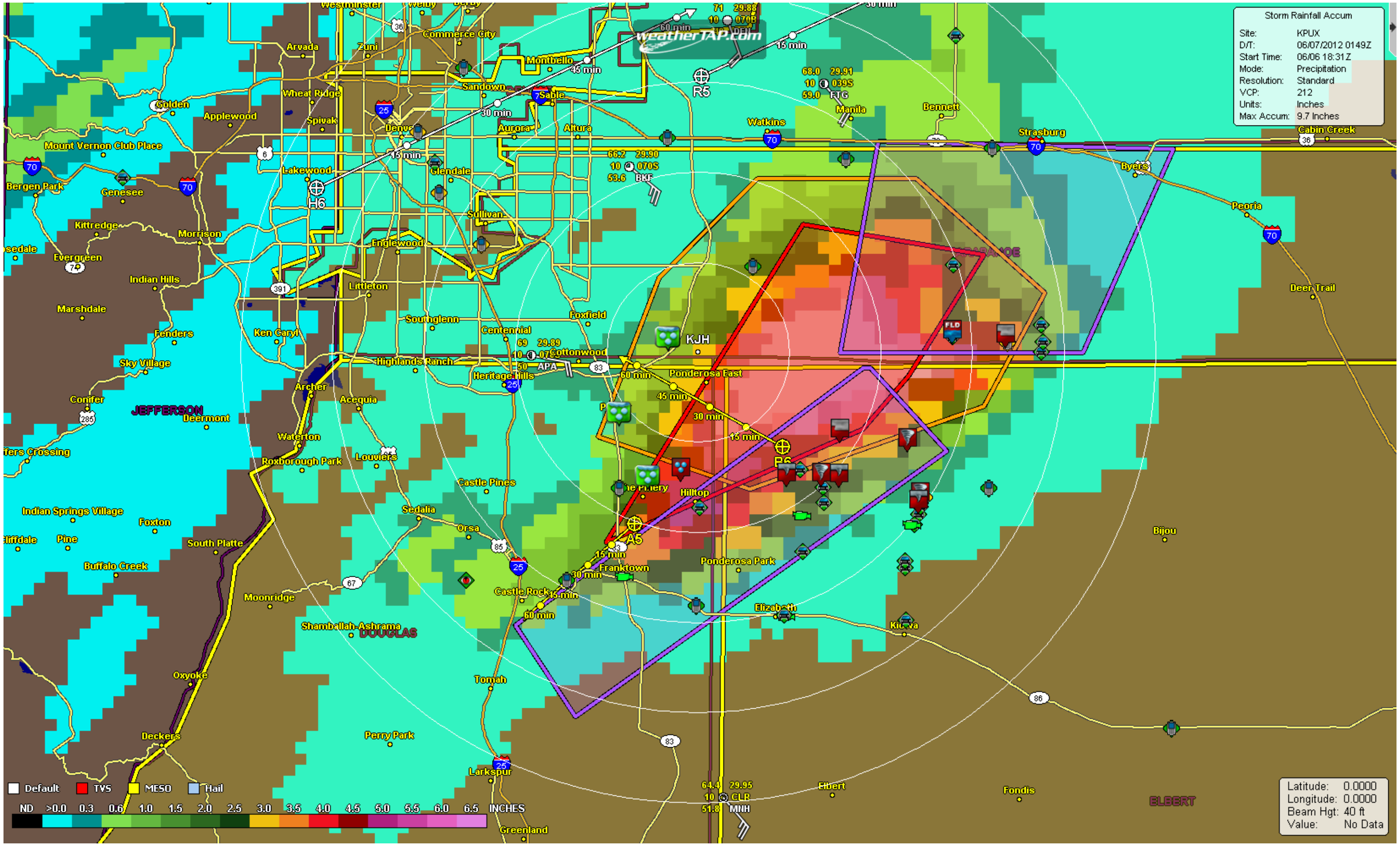


Predicted estimated rainfall



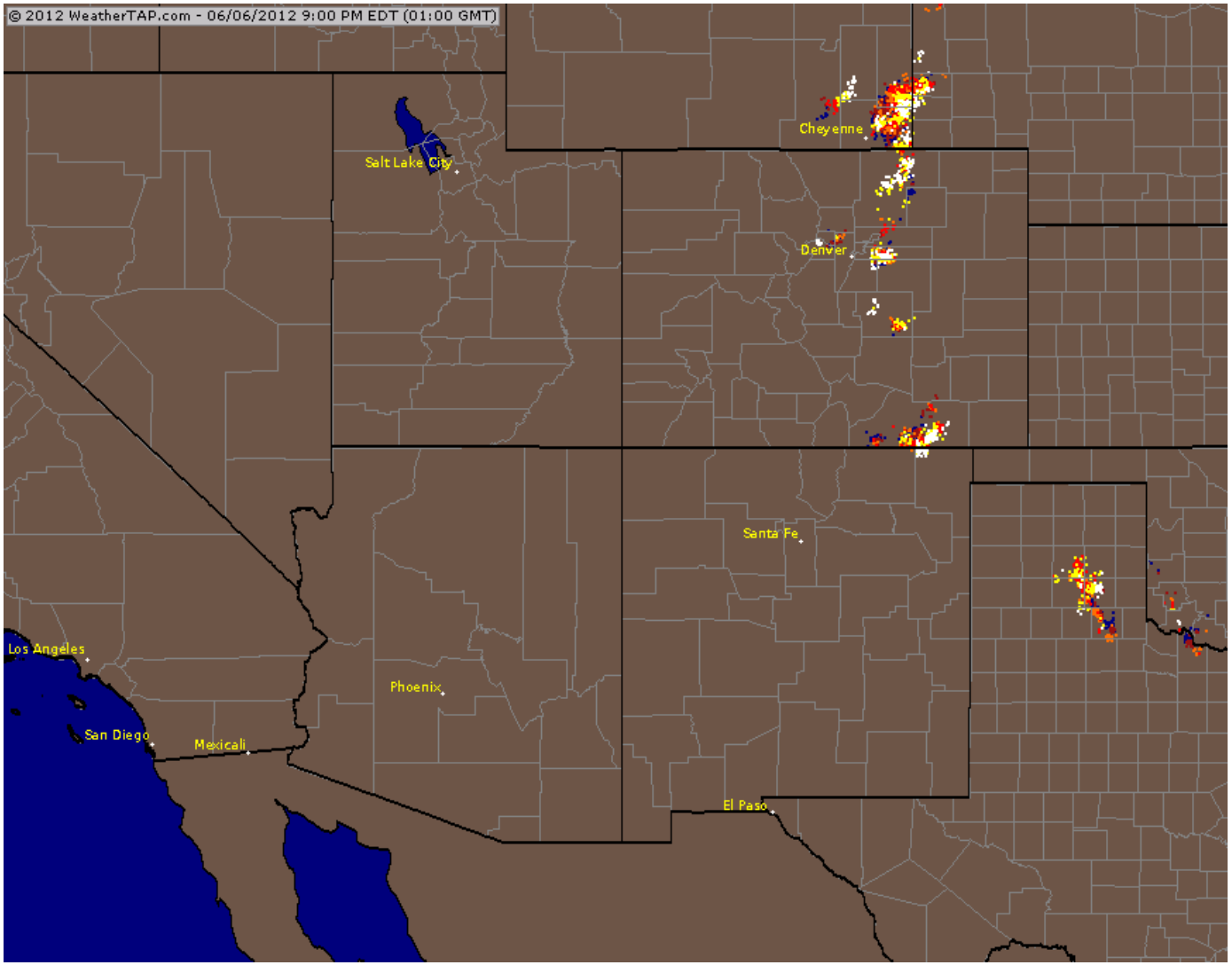
Flooding predicted 4-6 hours before it happens. Warning box in red.





Storm Rainfall Accum
Site: KPUX
D/T: 06/07/2012 0149Z
Start Time: 06/06 18:31Z
Mode: Precipitation
Resolution: Standard
VCP: 212
Units: Inches
Max Accum: 9.7 Inches
weatherTAP.com
Westminster
Arvada
Zuni
Commerce City
Montbello
Golden
Applewood
Wheat Ridge
Spivak
Sandown
Sable
Denver
Aurora
Altura
Watkins
Manila
Bennett
Strasburg
Cabin Creek
Byers
Peoria
Deer Trail
Mount Vernon Club Place
Bergen Park
Genesee
Lakewood
Glendale
Kittredge
Morrison
Sullivan
Evergreen
Englewood
Indian Hills
Littleton
Marshdale
Southglenn
Centennial
Foxfield
Fenders
Ken Caryl
Sky Village
Highlands Ranch
Cottonwood
Heritage Hills
Ponderosa East
KJH
APA
BKF
FTG
R5
H6
R6
A5
Conifer
JEFFERSON
Deermont
Archer
Acequia
Waterton
Roxborough Park
Louviers
Castle Pines
Hilltop
Indian Springs Village
Foxton
Sedalia
Orsa
Pine
South Platte
Buffalo Creek
Franktown
Ponderosa Park
Castle Rock
Moonridge
Shamballah-Ashrama
DOUGLAS
Elizabeth
Kiowa
Bijou
Oxyoke
Tomah
Deckers
Perry Park
Larkspur
Elbert
Fondis
ELBERT
Greenland
MNH
CLR
15 min
30 min
45 min
60 min
Default
TVS
MESO
Hail
ND >0.0 0.3 0.6 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 INCHES
Latitude: 0.0000
Longitude: 0.0000
Beam Hgt: 40 ft
Value: No Data

LTGCG shows back-building



Colorado Flood Threat Bulletin July 17, 2012

Flood Threat Bulletin
Flood Threat Outlook
24-Hr Radar Precipitation

About:
The CWCB offers a daily assessment of flood potential around the state, issued at 11:00 am each day from May through September.

Daily Statewide Flood Threat Bulletin and Map
This product is issued daily before 11:00 am and is used to identify areas of the state that are at risk of flooding. Updates can be issued as needed by weather situation.

7-15 Day Flood Threat Outlook (Updated Mon. and Thurs.)
This product is an outlook of the flood threat and precipitation amount and chance in the state over the next 15 days.

Statewide 24-hr Precipitation Map
This map is created by merging the 24-hr Storm Total Precipitation (STP) product observed regional WSR-88D and the MADIS observational database. Issued at 9:30 am every day.

Issue Date: Tuesday, July 17, 2012
Time Issued: 1014 AM MDT
Forecaster: Ryan Towell

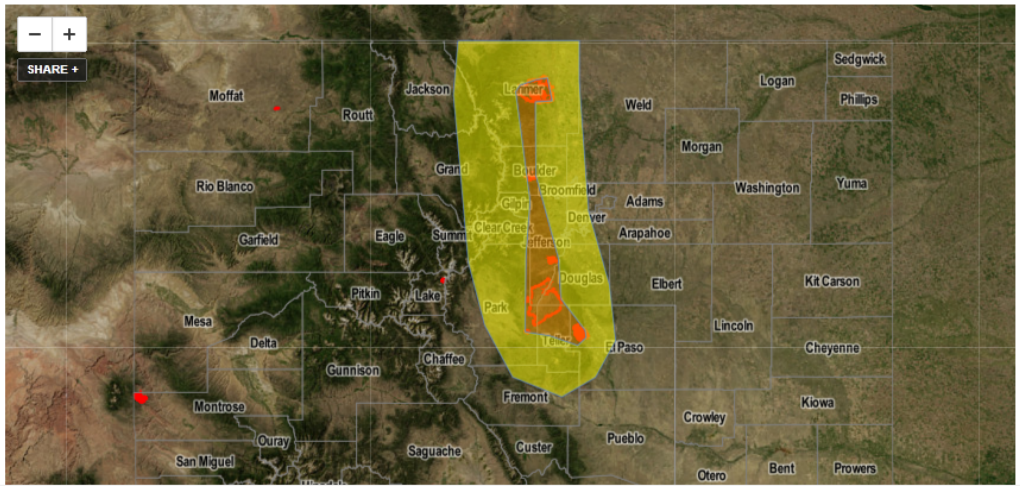
SCATTERED STORMS AGAIN THIS AFTERNOON AND EVENING; FLOOD THREAT IN FOOTHILLS

Water vapor satellite imagery this morning indicates drier air moving into the western portions of the State with monsoonal moisture being shunted a bit further east, mainly over central Colorado. With daytime heating, showers and storms will flare once again along the Continental Divide and into the Front Range, particularly after 1pm MDT. Storms will also develop into the foothills and parts of the plains as the afternoon progresses. Storms will generally move toward the east at 5 to 10mph.

The heaviest storms will be capable of cloud-to-ground lightning, hail and rainfall rates of 1.25" or so per hour. The foothills and burn areas, particularly those that received heavy rainfall yesterday including the High Park and Waldo Canyon burn scars, look to be most susceptible to flash flooding today. A Low Flood Threat is posted for the foothills, but a Moderate Flood Threat exists in the burn areas.

Showers and storms will be diurnally driven with much of the activity and the threat for flooding quickly dissipating after sunset.

Hover over the map to see today's flood threat bulletin.



Forecasts Provided By:
Dewberry

Links:

CWCB Home Page

CWCB Flood DSS

NWS Watches and Warnings

Urban Drainage and Flood Control District

Colorado Emergency Managers

NWS Radar:

Denver, CO

Grand Junction, CO

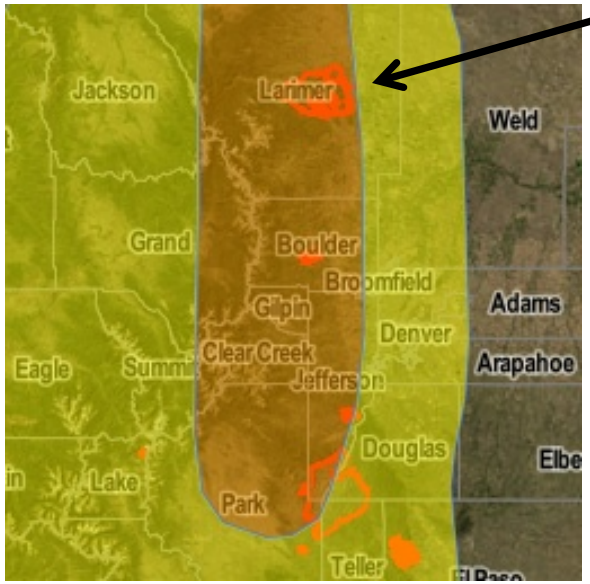
Pueblo, CO

Goodland, KS

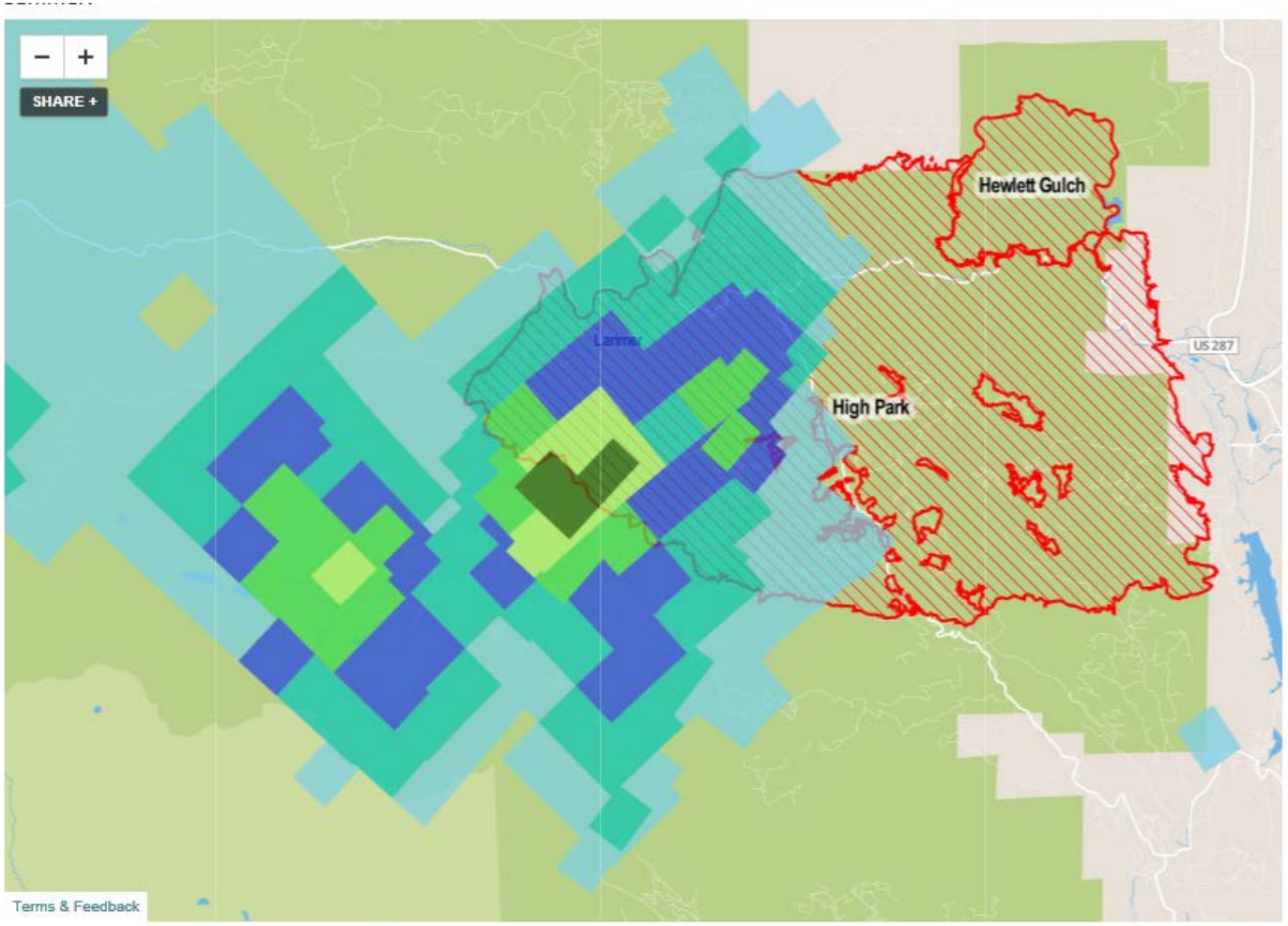
Got Comments?

CWCB is always looking for feedback on how to better serve the users of the Flood Threat Portal. Click the link below to submit your suggestions, questions, or

Flooding predicted in High Park Fire Burn Area



High Park Flood Thunderstorm Rainfall

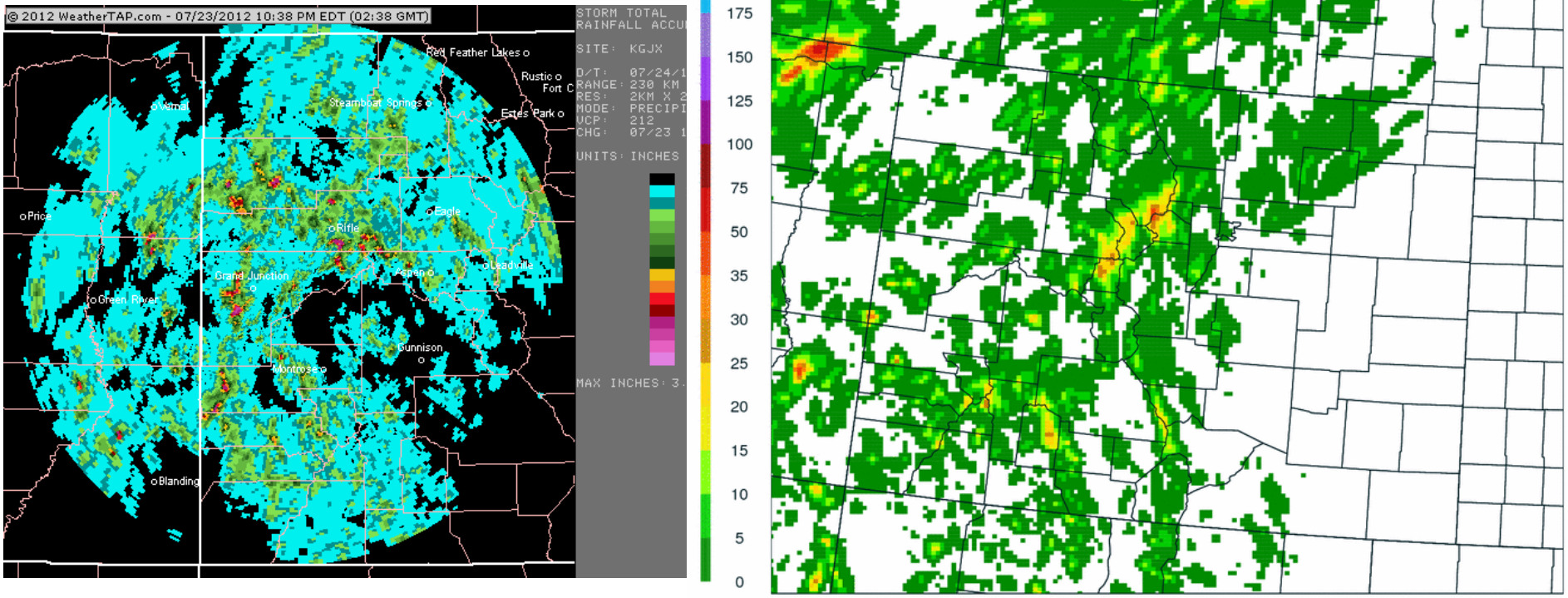


*Radar-estimated rainfall under 0.25 inches not shown

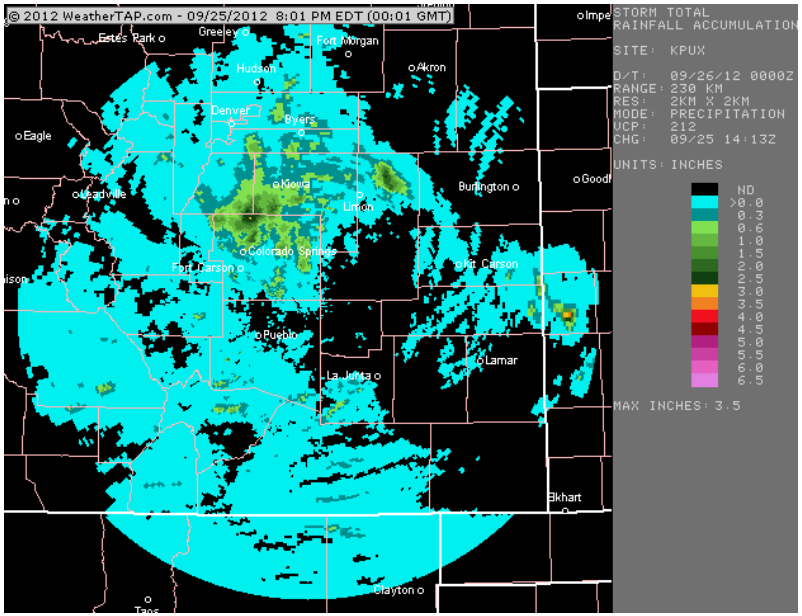
Fire-Burn

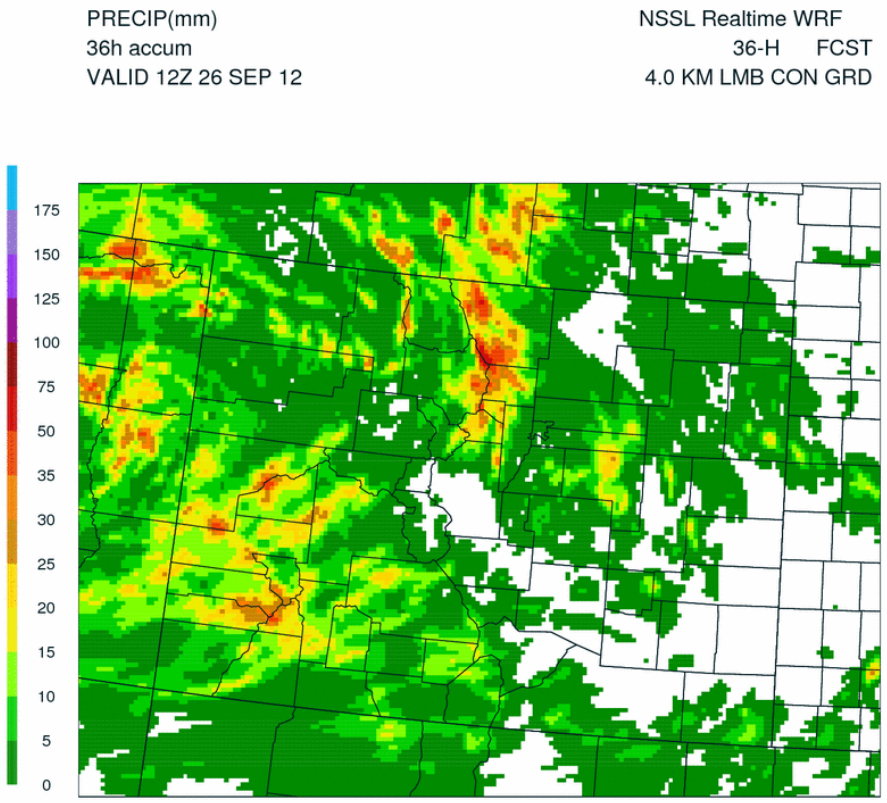
0.25" 0.5" 1.0" 1.5" 2.0" 2.5" 3.0" 4.0" 5.0" +5.0"

Miss on amounts and location

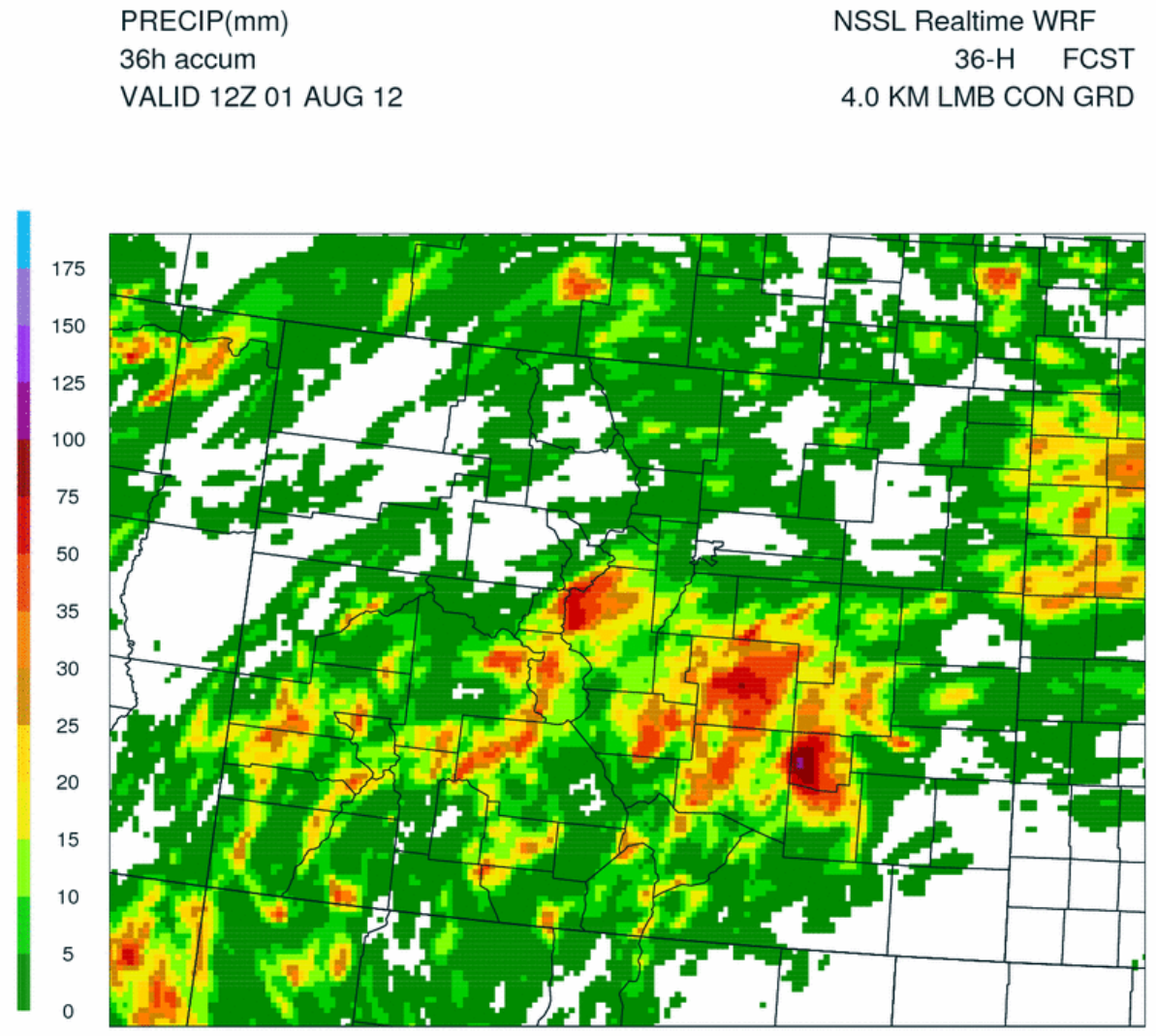


Miss: Timing and location

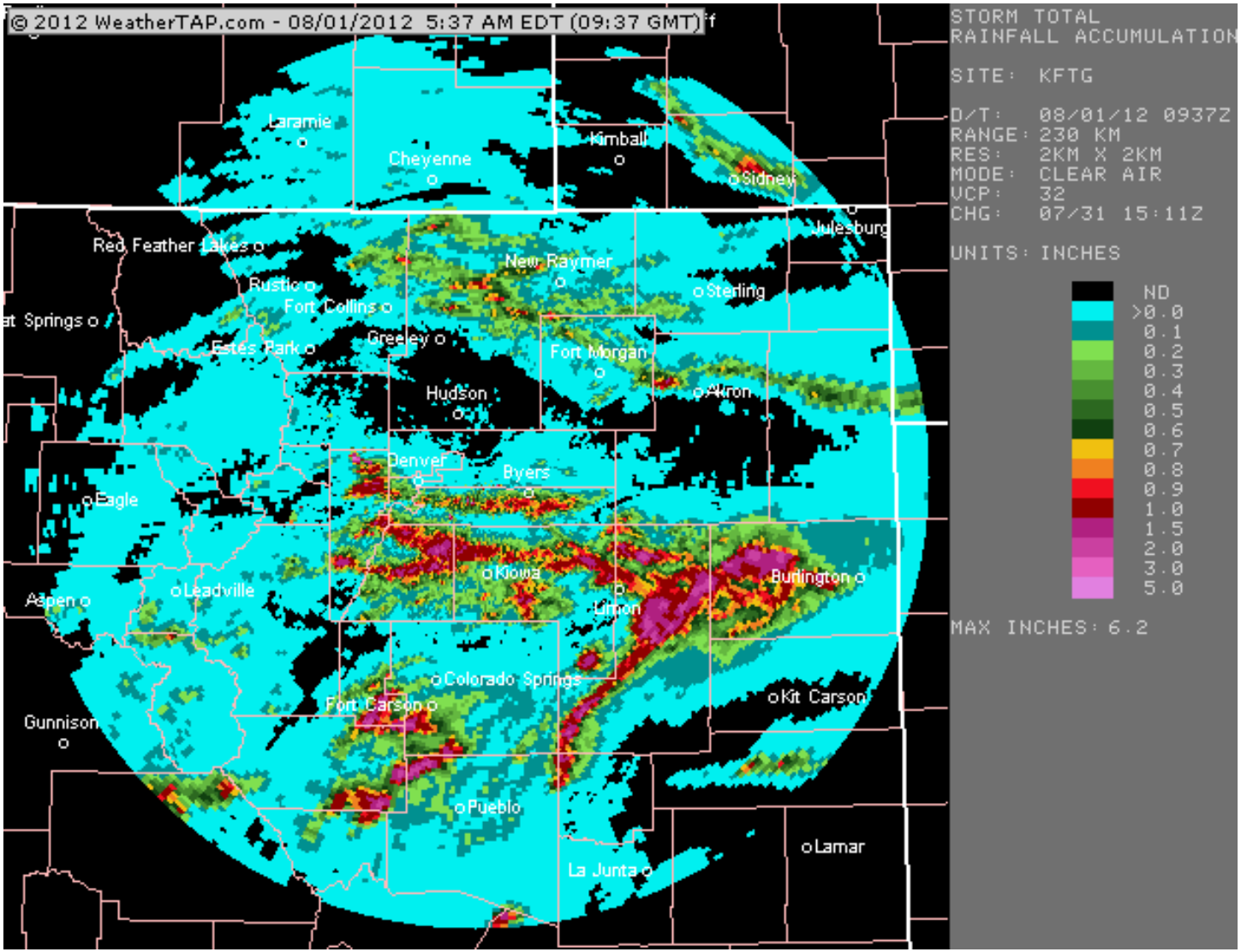




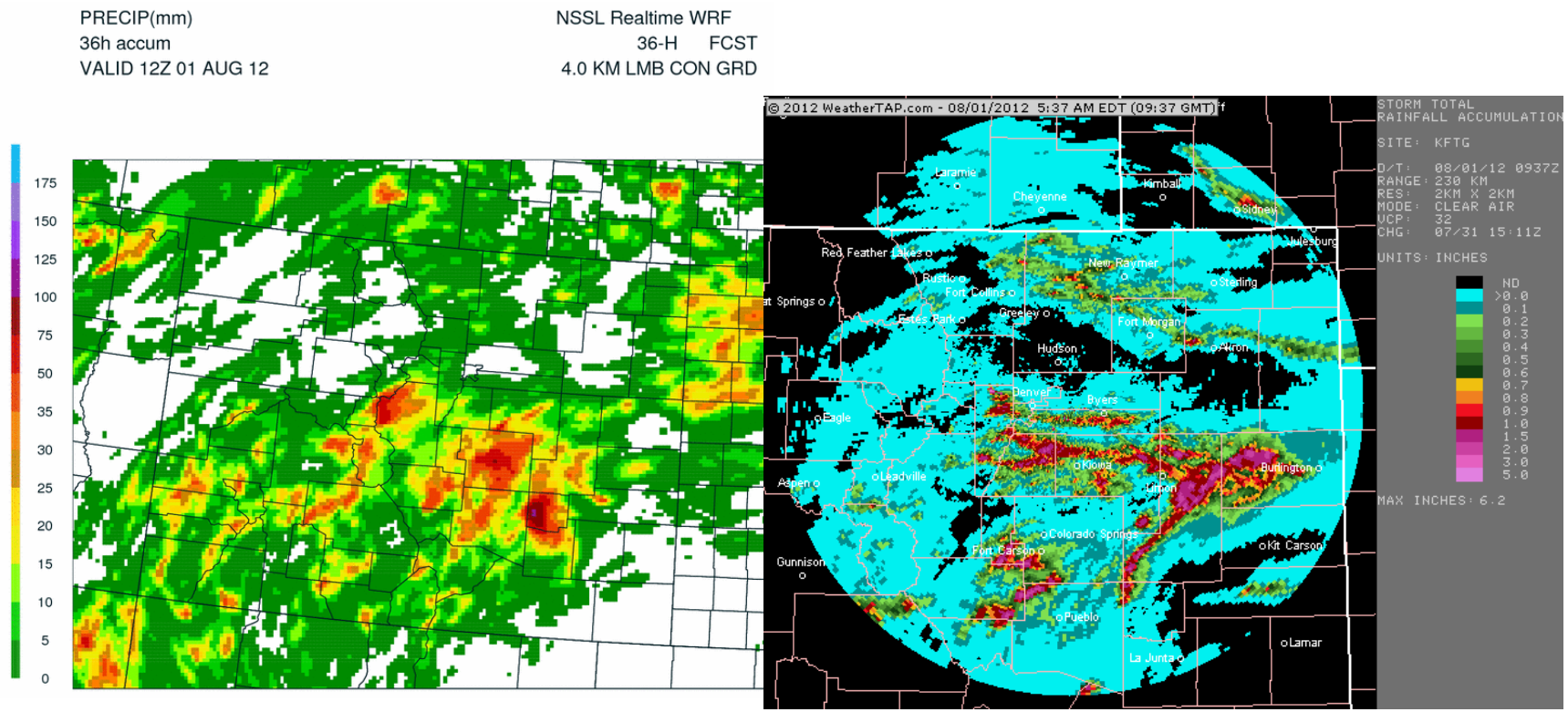
“Excellent guidance?”: July 31, 2012



Very good verification for July 31, 2012



“Roughly right; exactly wrong” but served meteorologists to alert them to significant day



Waldo Canyon west of Colorado Springs 7-30-12

$15 Million Damage due to flooding in Colorado Springs on July 31, 2012 plus rare tornado

World's second highest observed tornado
Mount Evans: > 13,000ft

Table Key weather events for the 2012 FTB program

Month	UDFCD (Denver metro) flood event days	NWS severe days	NWS flash flood days	Number and percent of flood days	Big flood event dates
May	1	8	2	8/31 (25%)	19-25
June	6	11	4	13/30 (40%)	4-8, 12-16
July	10	15	12	18/31 (60%)	3-9, 11-13, 15-17, 27-31
August	2	7	11	15/31 (50%)	9-11, 22-28
Sept	1	4	8	10/30 (30%)	25-29
Total	20	45	37	64/153 (41%)	

Flood day = NWS Flash Flood Obs or other observed flood plus either NWS severe weather day and >1.00in or >2.00in. Burn site exception.

Performance

Dewberry delivers winning projects that meet and exceed client expectations in a timely and accurate manner.

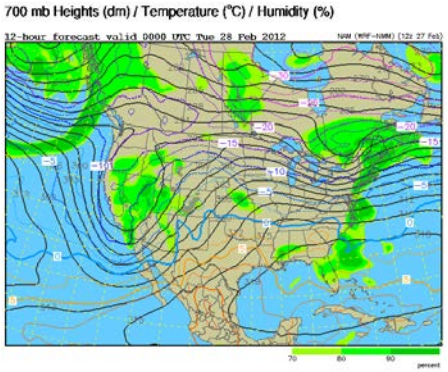
FTB Program WRF- Assisted Meteorologist Forecast Metrics Improved during storm season.

Month	Correct FTB Forecasts	Observed Flood Days missed	Flood Days Forecast that did not occur	Number of observed flood days per month	Number of observed flood days predicted	Number of observed flood days not predicted
May	26/31	3	2	8	**5 (62%)**	3
June	26/30	3	1	13	**10 (79%)**	3
July	27/31	1	3	18	**17 (94%)**	1
Aug	25/31	1	5	15	**14 (93%)**	1
Sept	28/30	2	0	10	**8 (80%)**	2
Total	**132/153 (86%)**	**10**	**11**	**64**	**54 (84%)**	**10 (16%)**

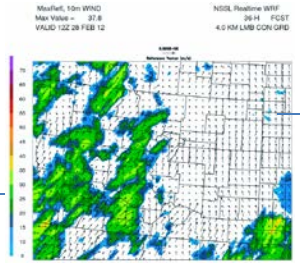
Areas of continuing evaluation

- Spatial location: 75% were +/- 25 miles for peak rain areas on plains; more in mountains.
- Temporal occurrence: >80% of peak rain areas were +/- 2hrs of occurrence.
- Amount of rainfall: work in progress. Varied from 40% below to 200% or more over.
- NSSL-WRF assisted both out-of-state and “rusty” meteorologist significantly.
- Not quite ready for objective DSS application.

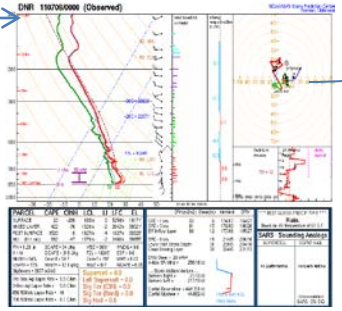
Dewberry's Integrated Flood Information Decision Support System (IFINDSS)

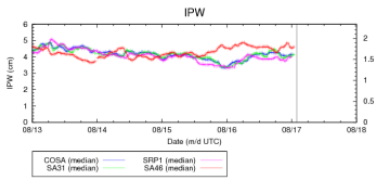


Upper air and surface observations

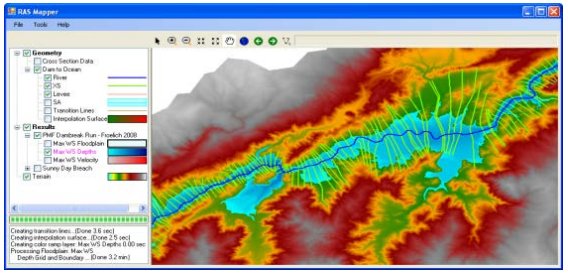


Forecast radar and soundings





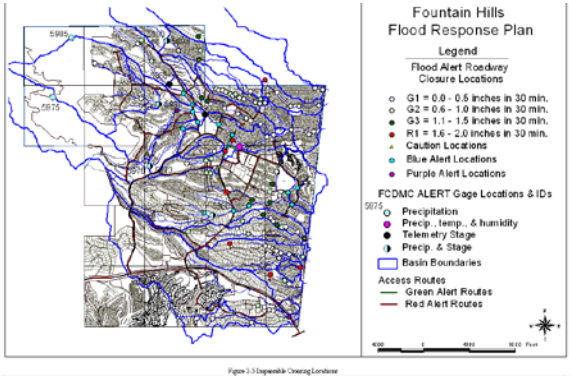
GPS-IPW moisture



Forecast floodplain inundation scenario

- Critical facilities
- Evacuations
- Resource allocations

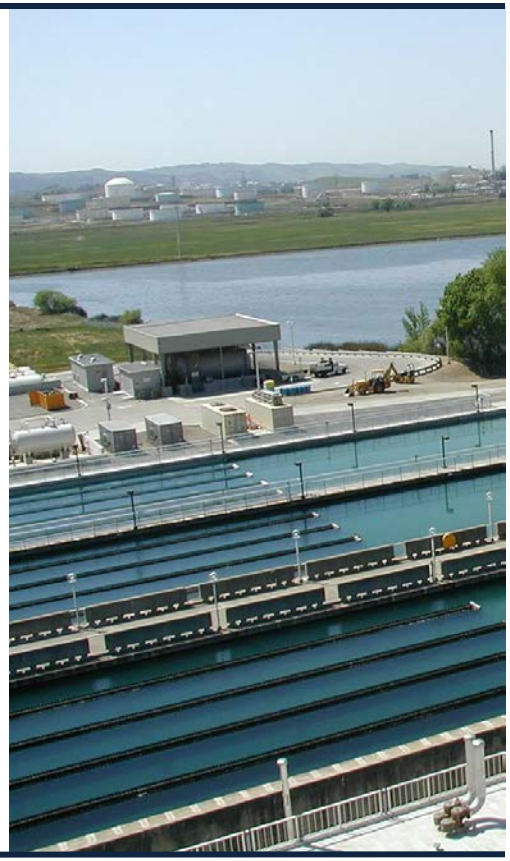
Pro-active agency responses



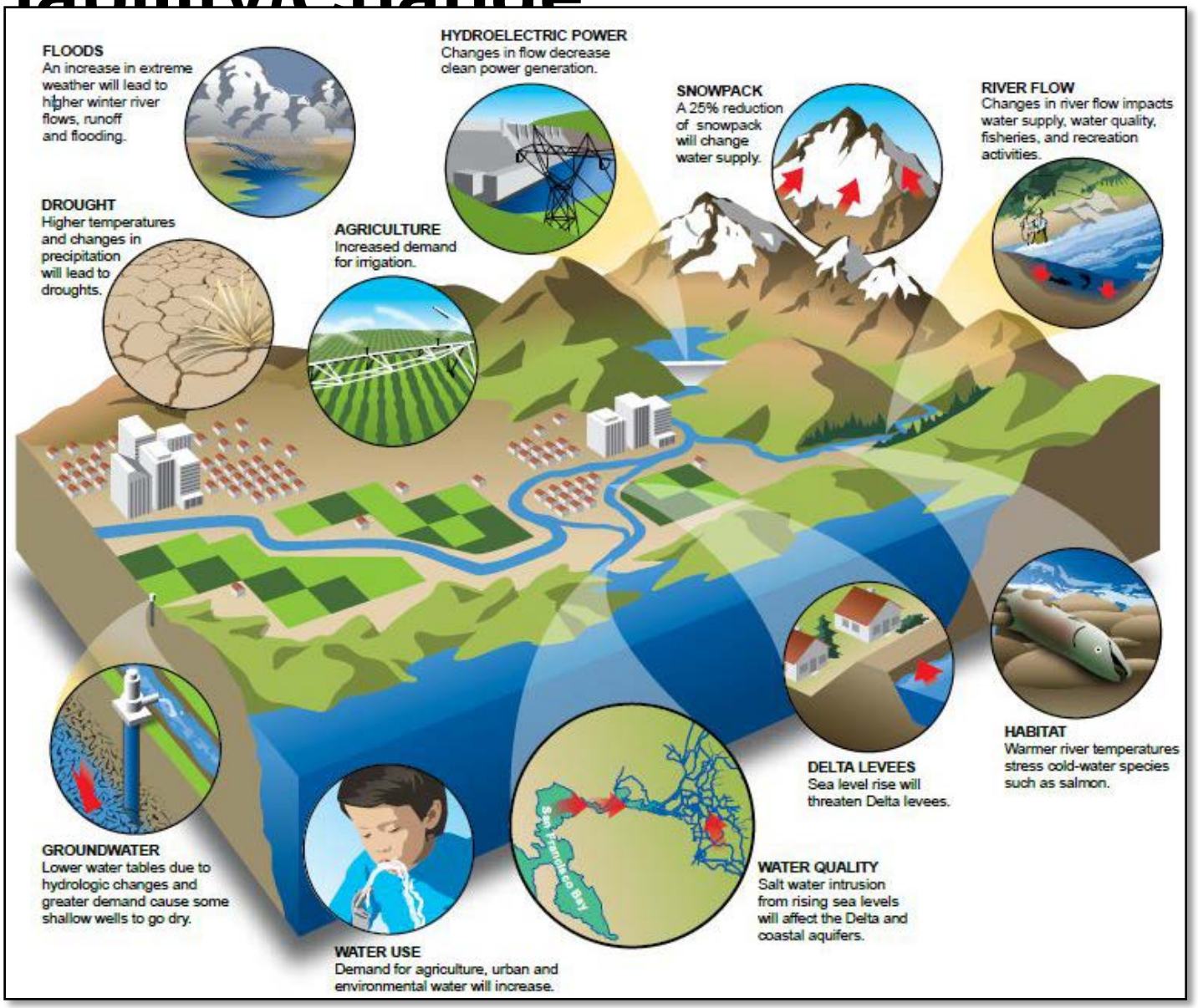
Flood Response Plan actions

Water Facilities and Climate Change

A need exists for Water and Wastewater utilities to better understand their risks due to increasing climate variability. To achieve this, value-added services in GIS and web technologies; Climate Change and Water Resources expertise; and data analysis will be required.



Potential Impacts of Climate Variability/Change



Climate change is reality in New England

- New England has already started to feel the effects of global climate change.
- Snow cover is decreasing and spring arrives earlier.
- Scientists predict that we may be headed for a Boston climate much like that of Charlotte, North Carolina, or Atlanta, Georgia.
- What is in store for Massachusetts and the other New England states—and what could happen to Boston.
- How could coastal flooding affect us?
- What is the likelihood of extreme weather such as nor'easters and ice storms and combinations like Superstorm Sandy?

Coastal storms and hurricanes impact floodplains

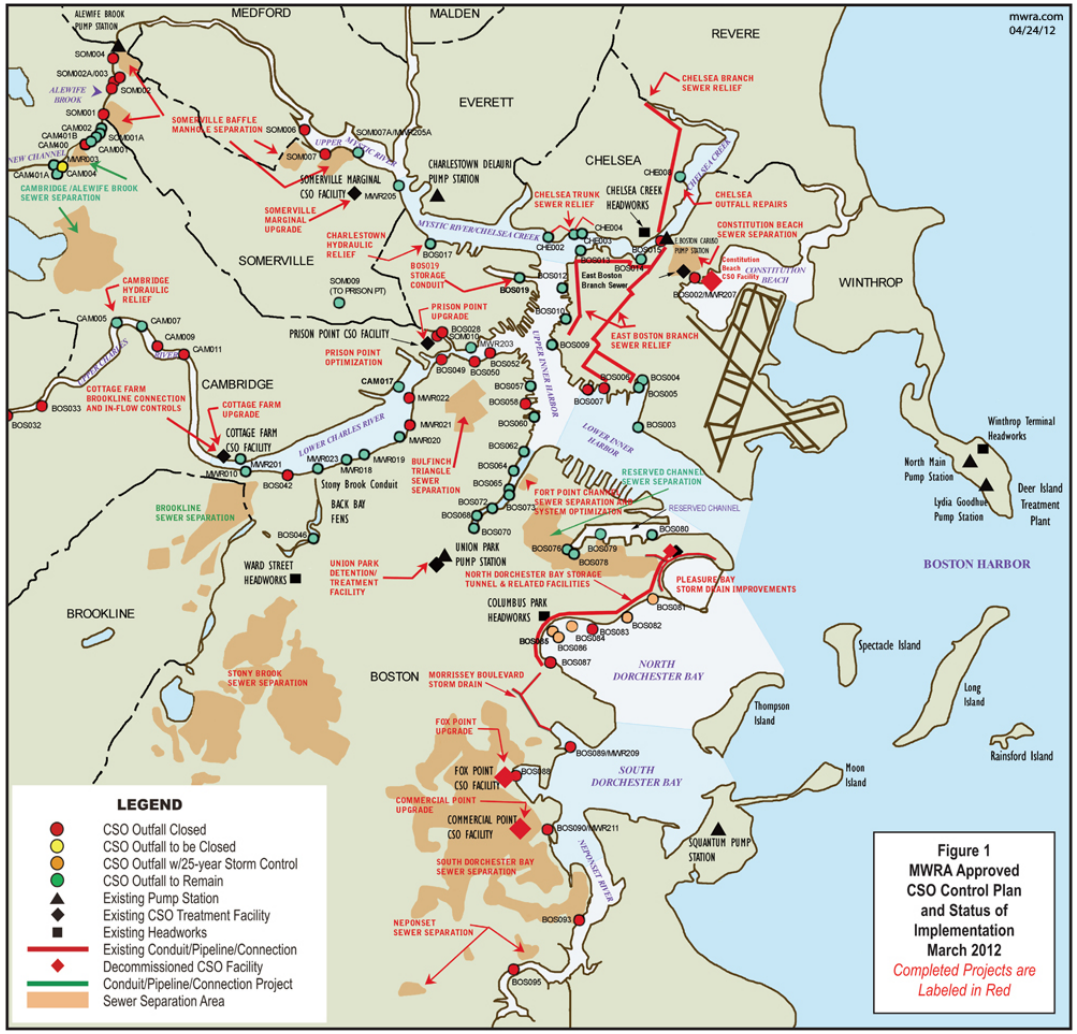
1. Increased coastal storm and/or hurricane frequency could impact both floodplain flooding and storm surge impacts.

2. Significant area can be impacted.

3. Impacts on dams and levee design and capabilities will be impacted.

4. Design storms may need updating.

5. Evacuation plans (EAPS) need to be updated.



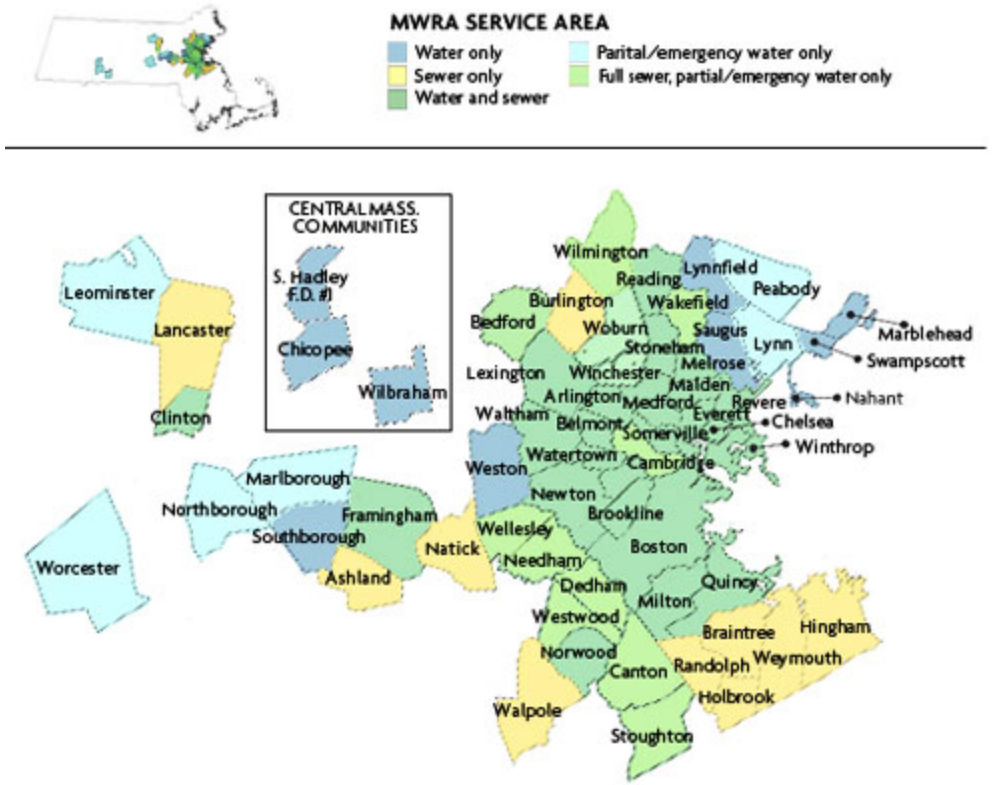
MWRA CSO Region

•Changing precipitation/storm frequencies and intensities could impact ability to treat street runoff and sewage effectively.

•Extended dry periods increase street pollutants washed into system during precipitation events.

• Design storm characteristics of spatial and temporal values could be impacted by changing storm sizes, intensities and frequencies.

•Use of WSR-88D Doppler radar to develop design storms using past 15 years of data could enhance spatial and temporal information for infra-



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Water Supply System Vulnerability to CC

•Long term drought could impact precipitation seasonally in the key drainage areas.

•Flooding from extreme winter/coastal storms and hurricanes could produce flooding that damages supply system infra-structure.

•Extended heat waves could both increase demand and ET water loss.

•Reduced hydro-electric generation during periods of extended low flow and reservoir depletion.

Dewberry

What are the Consequences of Climate Change?

Direct Impacts

Drinking Water Supply: water supply and runoff, pipes, reservoirs, pumps, valves, treatment equipment.

Drainage Systems: storm sewers, ditches, etc.

Major Irrigation Systems: canals and reservoirs

Major Flood Control Systems: dikes, levees, floodgates.

Indirect Impacts

Loss of Services: Business is paralyzed or decreases

Health: Spread of diseases from WW shutdown.

Distribution Lines: Increased flooding

Environmental: contamination, increased turbidity

Economic: System revenue/costs impacted

Applying Climate Science to Water Utilities

What information is relevant from Global Climate Models (GCMs)?

		Issue	Climate Model Variable
Water Supply	1	**Long-term supplies – mean annual basin yield**	Annual avg. temp. and precipitation
	2	**Long-term demand and supply**	Warm-season temp. and precipitation
	3	**Shift in seasonality of runoff – snowmelt-dominated areas**	Monthly temperature
Flooding	4	**Seasonal Floods**	Winter and spring precipitation
	5	**Major storms / cyclones**	Frontal systems; cyclone formation and track
Water Quality	6	**Biological Oxygen Demand**	Annual, seasonal, monthly air temperature
	7	**Dissolved Oxygen**	Annual, seasonal, monthly air temperature
	8	**Saline intrusion of groundwater**	Sea level rise; annual temperature and precipitation
	9	**Algal bloom**	Annual, seasonal, monthly temperature
	10	**Turbidity**	Daily, hourly precipitation intensity

Perspectives from Water Utilities

The following are examples of pro-active planning measures and assessments in response to increasing vulnerability from climate change.

Denver Water

Through several climate initiatives, they engaged in sensitivity analyses, a paleo-climate extrapolation of stream flows from tree ring data, and a vulnerability study.

Results indicated potential changes in the timing and volume of runoff across more than one-hundred GCMs.

NYC Dept. of Environmental Protection

Designed an integrated climatic model that assessed the that quantity and quality of NYC's water supply, incl. (1) total water quality, (2) turbidity, and (3) eutrophication.

Other results incl. probabilities of reservoir refill and drawdown; reservoir phosphorous and chlorophyll concentrations and restrictions in water use due to eutrophication.

Portland Water Bureau

Evaluated four GCMs selected to represent a range of temperatures and precipitation patterns for the Pacific Northwest.

Results incl. assessment of impacts of changes in temperature on water demand. These changes were then used as inputs into the 'Supply and Transmission Model', a system used to study effects on water supply performance on the existing system.

Seattle Public Utilities

Created a down-scaling study of three potential future climate scenarios, which were then run as inputs in the 'Distributed Hydrology, Soil-Vegetation Model' to develop hydrologic datasets.

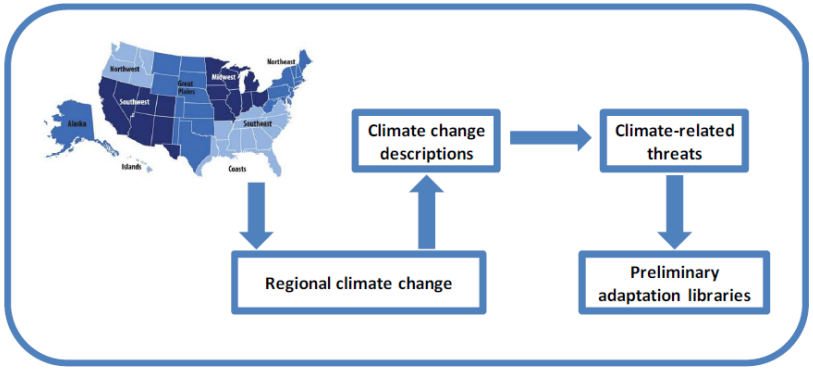
Results lets to adaptation scenarios.

Climate Resilience Evaluation & Awareness Tool (CREAT)

Developed by the EPA, this software assists drinking water and wastewater utility owners and operators in understanding potential climate change threats and in assessing the related risks at their individual utilities. CREAT provides users with access to the most recent national assessment of climate change impacts for use in considering how these changes will impact utility operations and missions.

Features

1. **Serves as a stand-alone risk assessment with adaptation options and their effectives in reducing impacts.**
2. **CC information at regional and local levels to assess threats and environmental / economic consequences.**
3. **Supplies library of drinking water and wastewater utility assets.**
4. **Lists CC impacts to affected drinking water and wastewater utilities.**
5. **Provides recommended strategies**



Translating Regional Climate Descriptions to Water Sector Threats and Adaptation Measures

Putting climate change science to work

SOME PROJECT EXAMPLES

Platte Basin "connects" to different ENSO Cycles

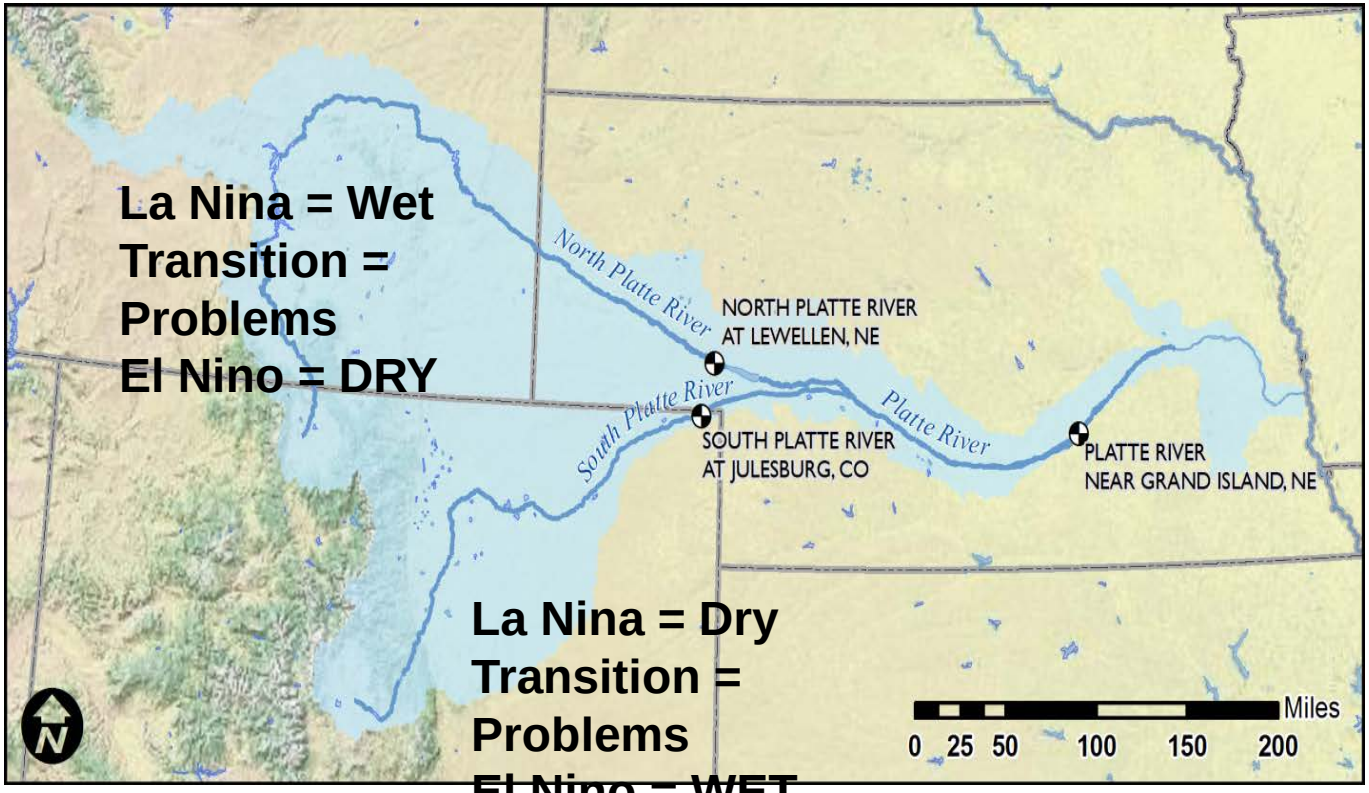
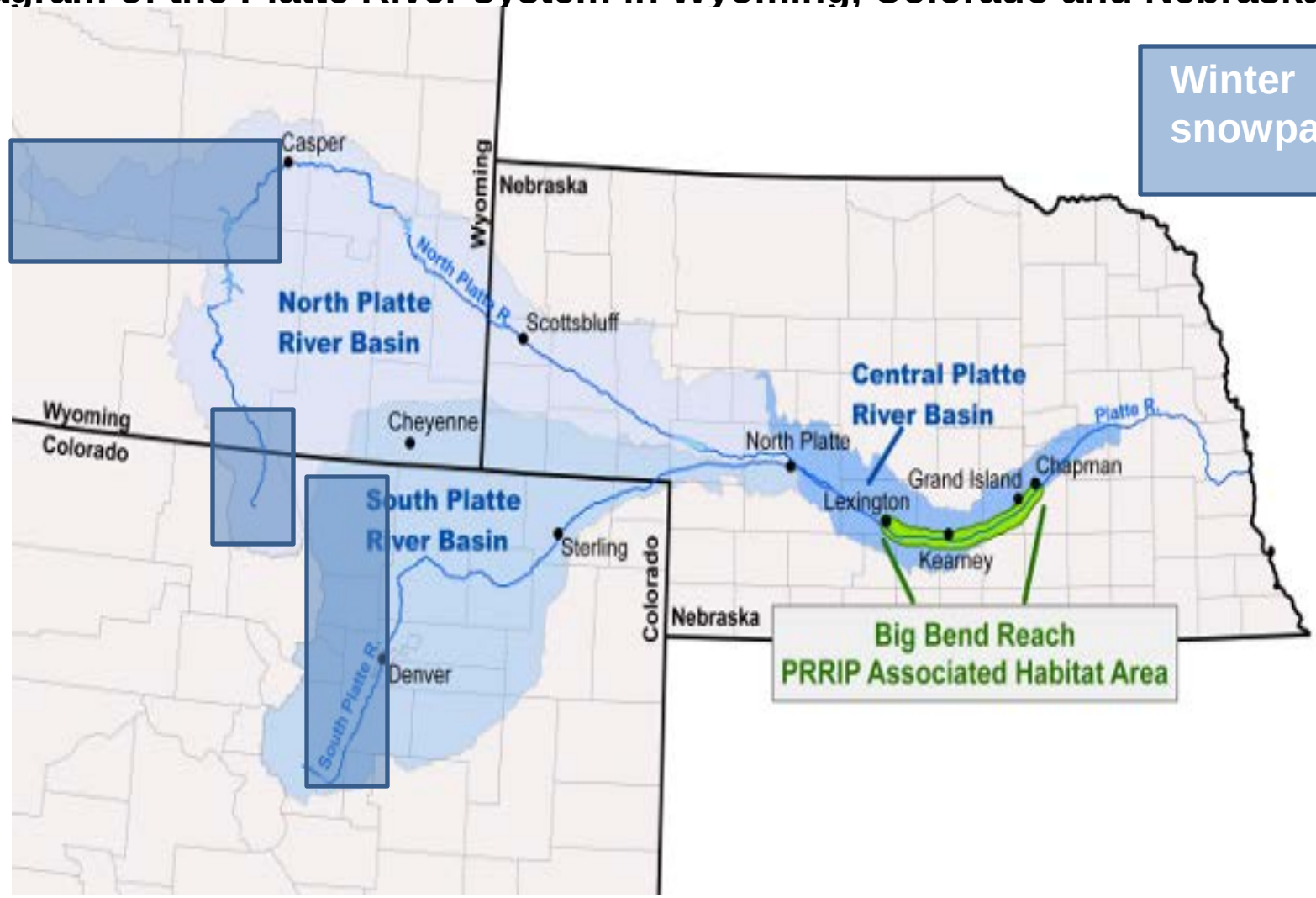


Diagram of the Platte River system in Wyoming, Colorado and Nebraska

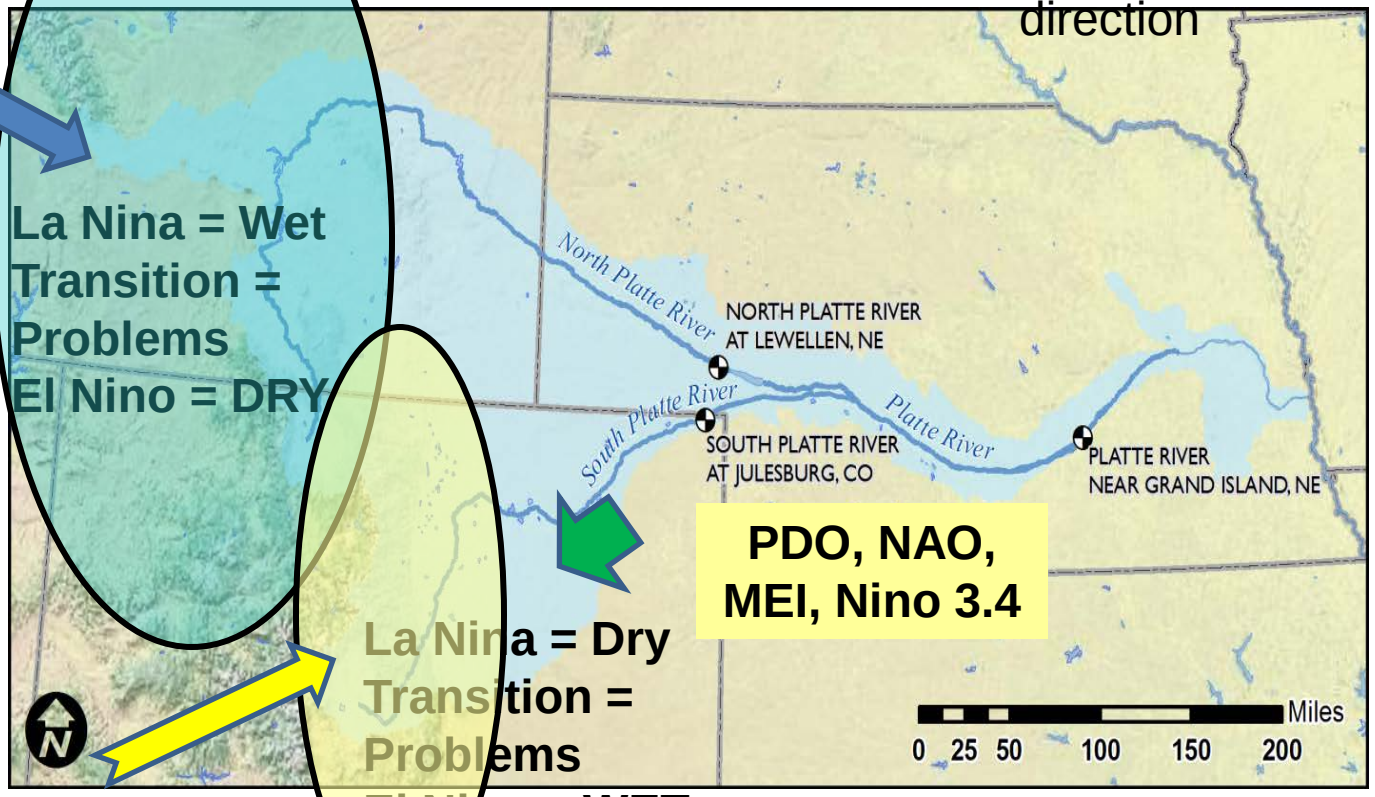


Platte Basin "connects" to different ENSO Cycles/HCI

Winter Surface storm wind direction

Winter 700-500mb wind direction

Nino 3.4
MEI, PDO

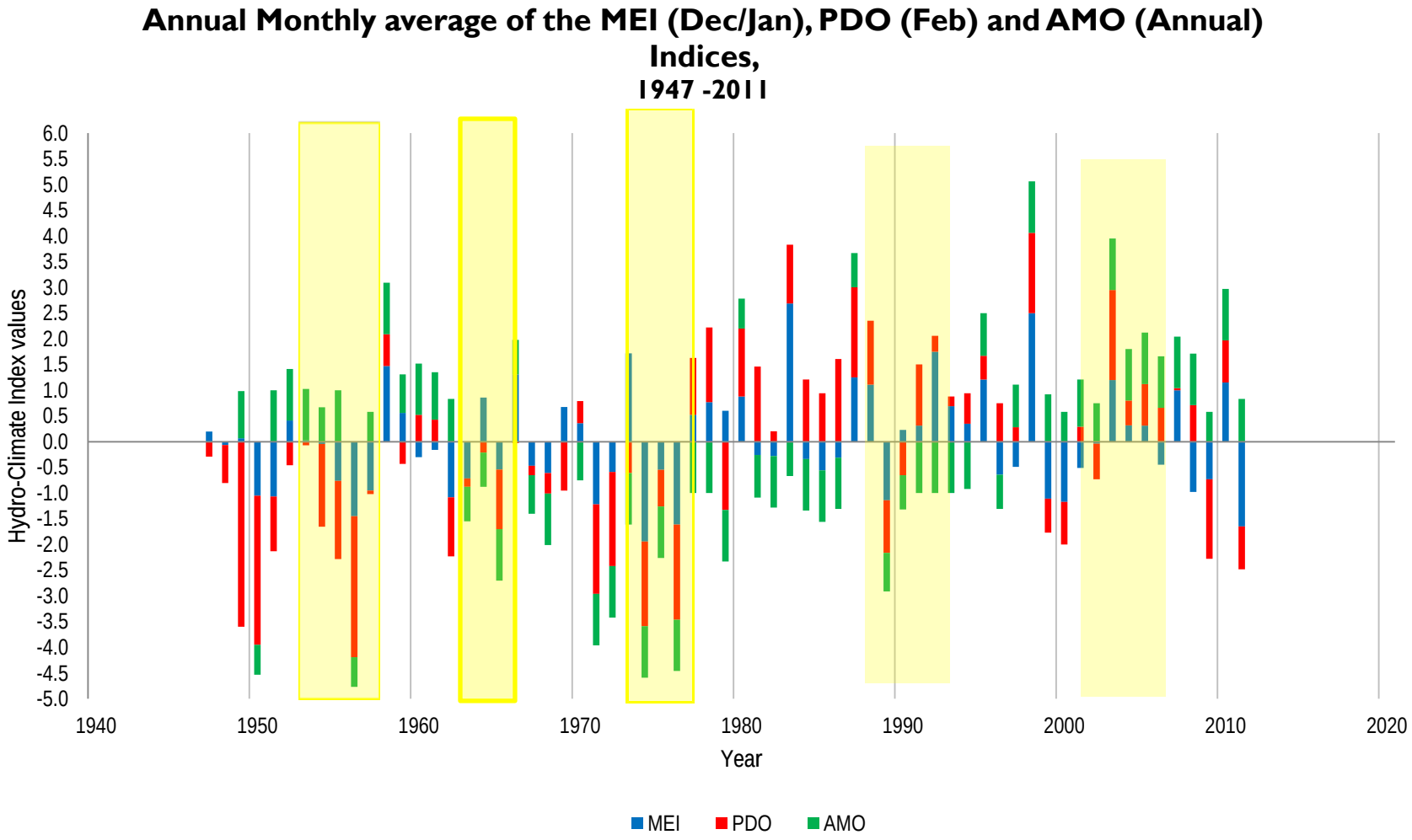


La Nina = Wet
Transition = Problems
El Nino = DRY

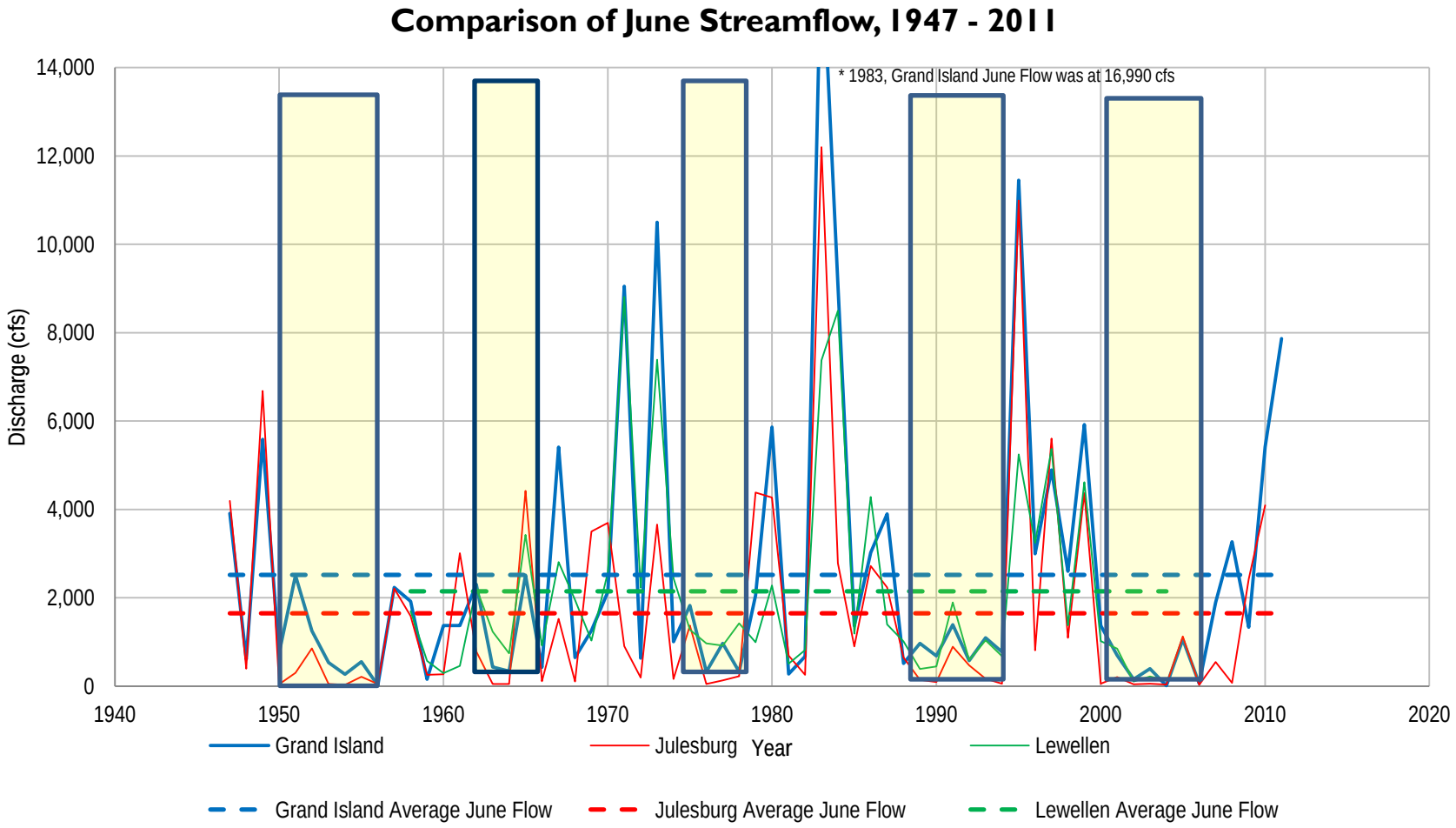
PDO, NAO, MEI, Nino 3.4

La Nina = Dry
Transition = Problems
El Nino = WET

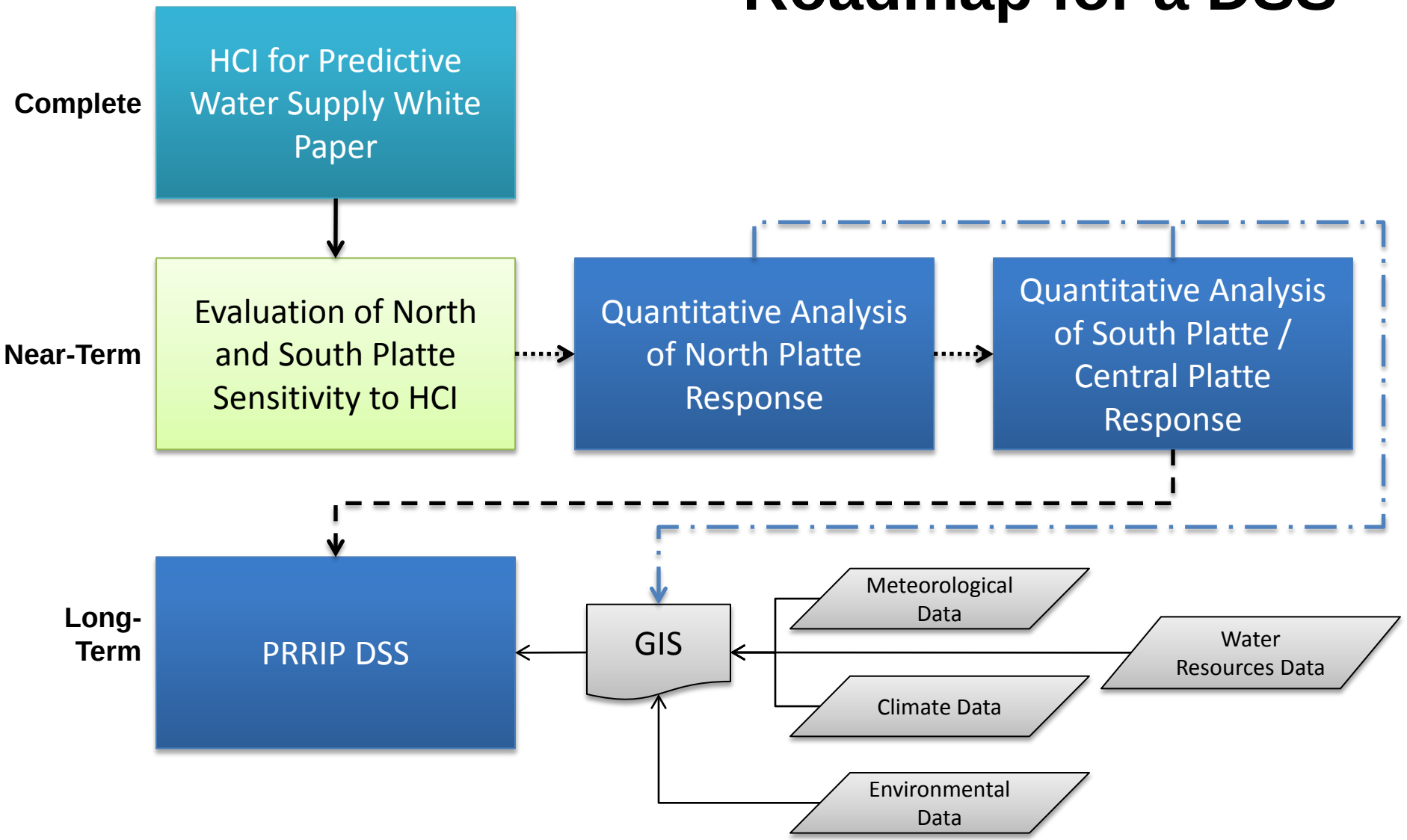
Comparison of HCI phase to low flow years on Platte



MEI-PDO-AMO indices “capture” most droughts early



Roadmap for a DSS



Projects

Title: Climate Change Risk Assessment and Adaptation Planning at Airports
Client: Transportation Research Board NAS-NRC

Overview

1. Revise Research Plan
2. Airport Adaptation Analysis
3. Characterize Airport Vulnerabilities and Risk
4. Develop Potential Airport Adaptation Actions
5. Screening Tool Design
6. Guidebook / Final Report

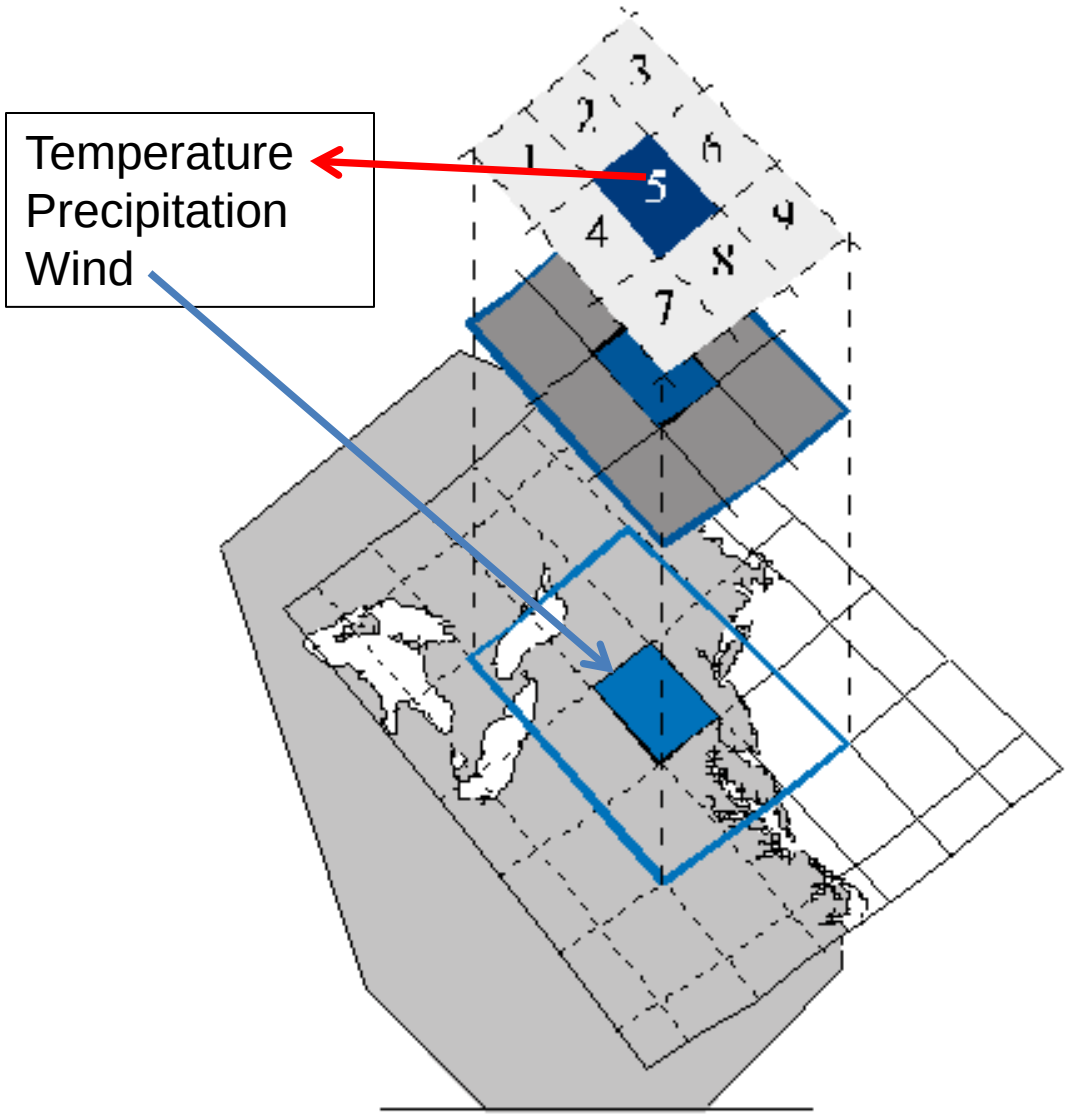
Airport Climate Risk Operational Screen Tool

- Seasonal avg. / max. temperatures
- Sea Level Rise
- Frequency of Precipitation/Severe Events
- Increase in Drought Events
-Hurricane Intensity and Frequency

Climate change Impact
Climate model downscaling

- Based on GCM-AR4 output and ***statistical temperature-based downscaling***

- **Dynamic downscaling = better answer**

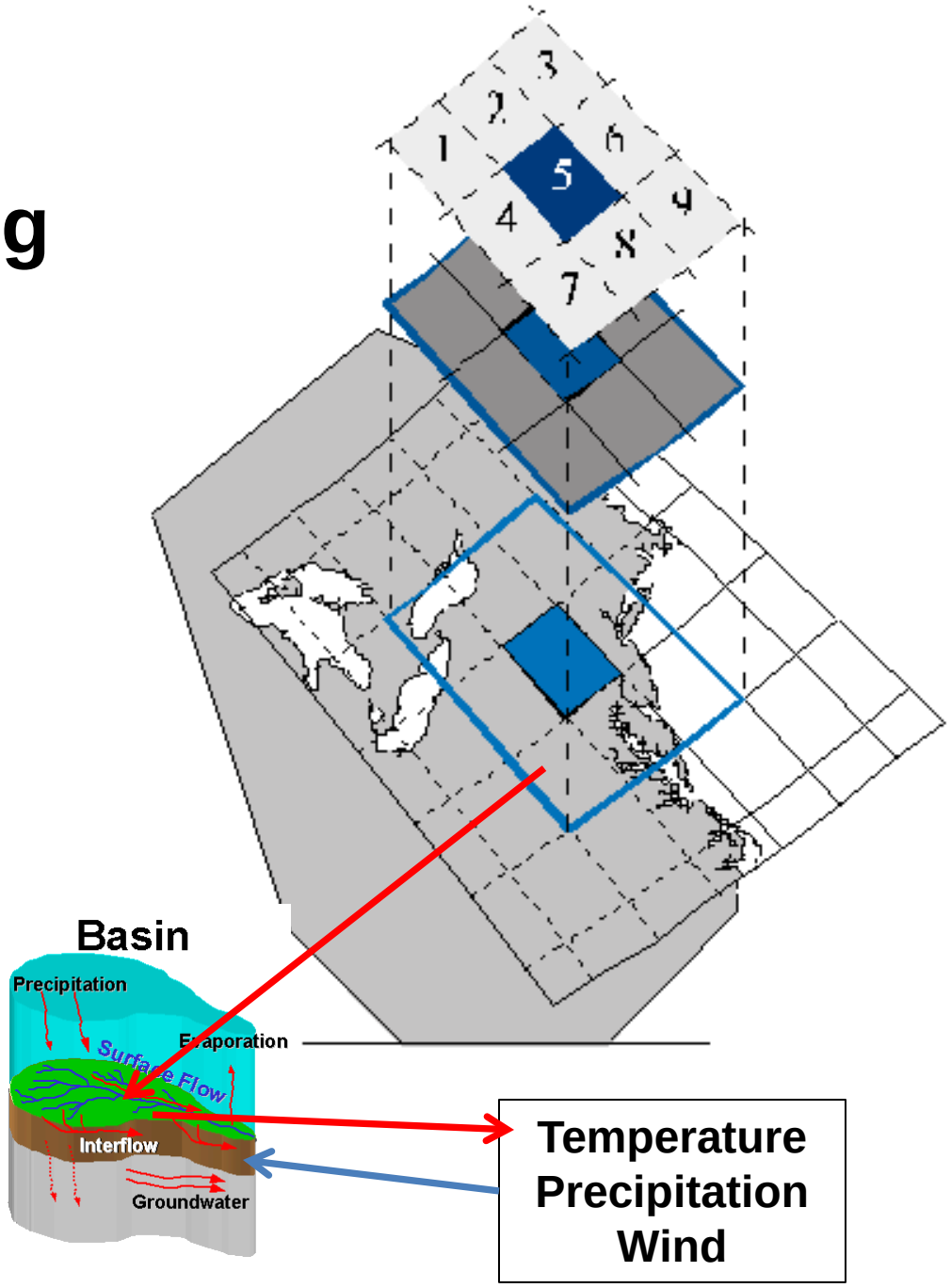


Adaptation: Climate downscaling

- Based on GCM-AR4 output and ***statistical temperature-based downscaling (SimClim)***

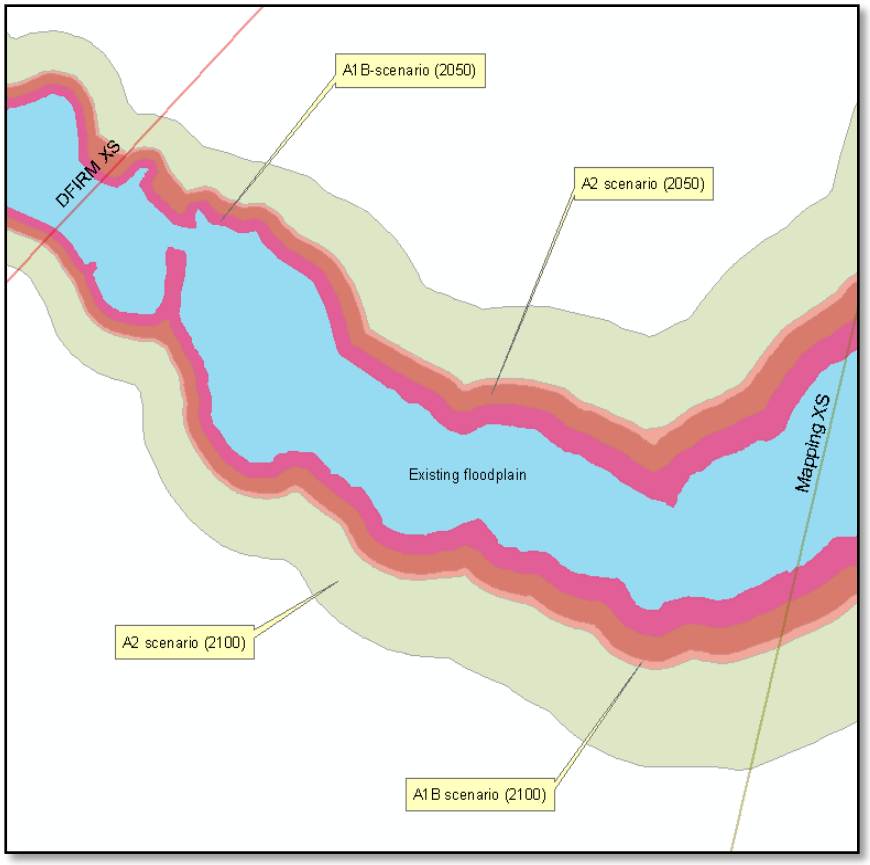
- Based on a statistical relationship between temperature and precipitation in basin

- ***Dynamic downscaling by linking NCAR-MM5 or WRF to GCM*** – better physical cause-effect connections to basin scale



Use GCM scenarios to develop floodplains

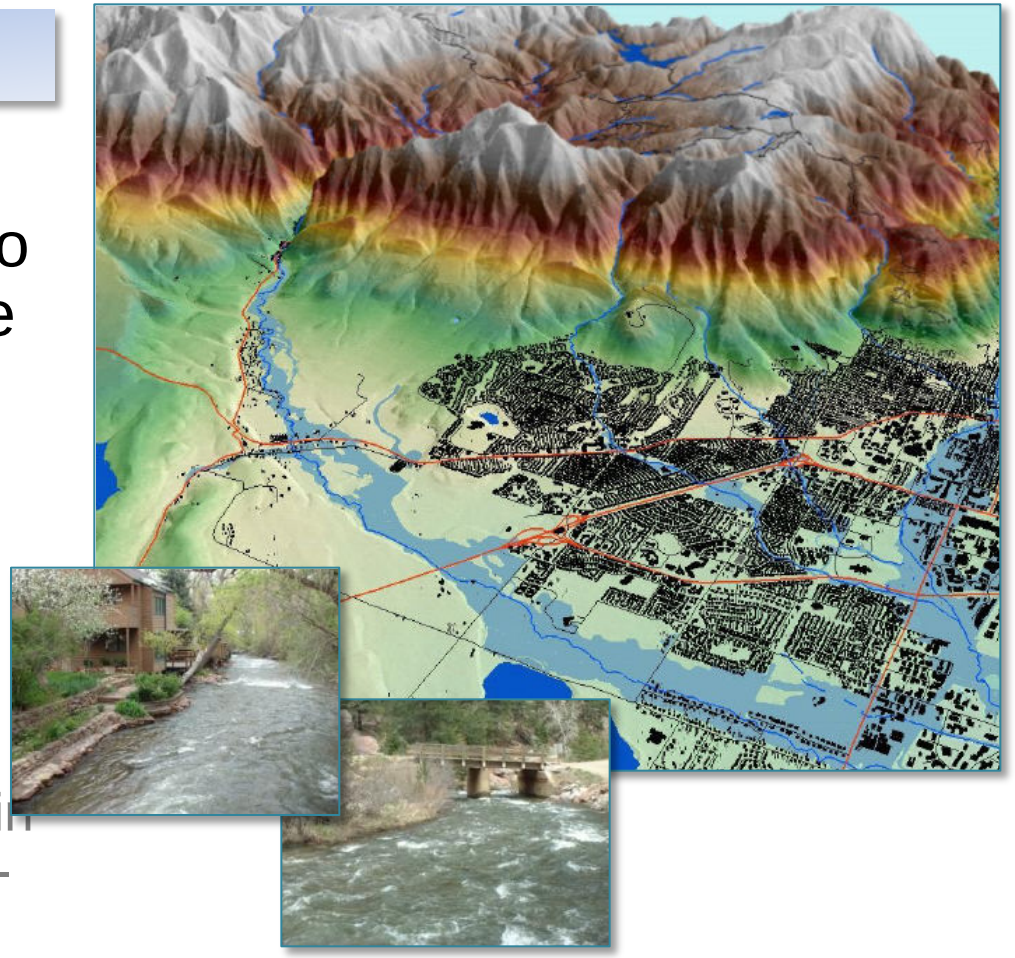
- Use each of the downscaled solutions for the key GCM scenarios of the floodplain definition.
- Use this technique to look into the 50-yr to 100-yr future.
- Consider phased adaptation



City of Boulder
South Boulder Creek Floodplain Analysis

Project Details

- 140 sq mile basin
- Previous studies failed to adequately delineate the floodplain and gain public approval
- Gained FEMA, federal, state, local and public approval
  - First time design storm driving the 100-yr floodplain was approved using radar-designed, design storm

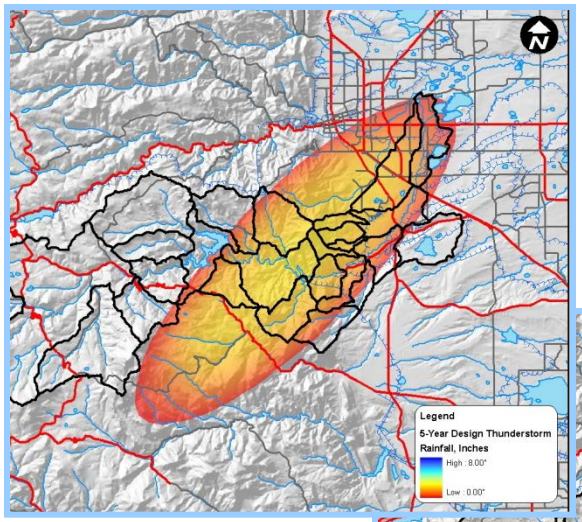


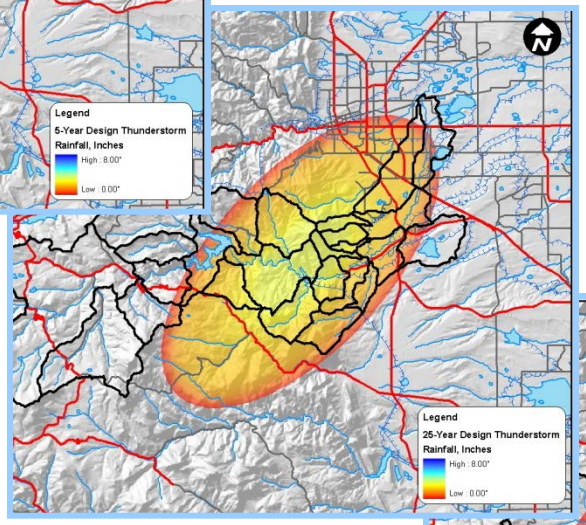
South Boulder Creek flooding events and 100-yr floodplain flooding simulation in Mike-Flood

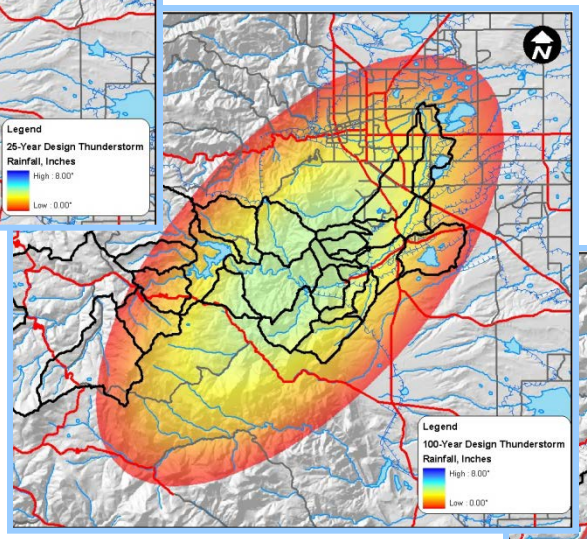
2-, 25-yr, 100-yr, 500-yr Design Local Storms based on WSR-88D radar observations

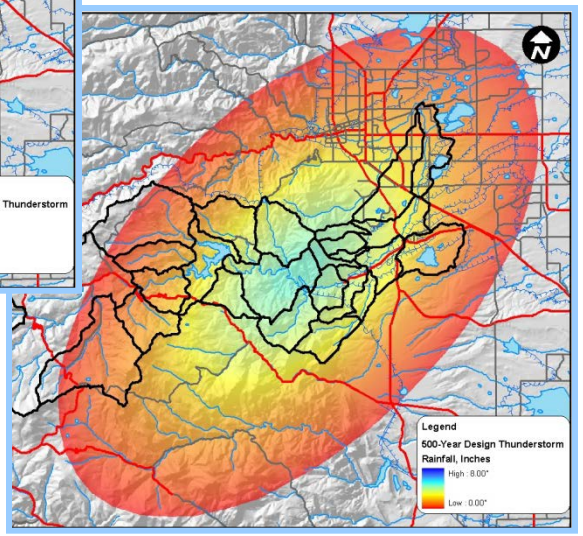
Identified regional storms producing key rains.

Determined spatial characteristics





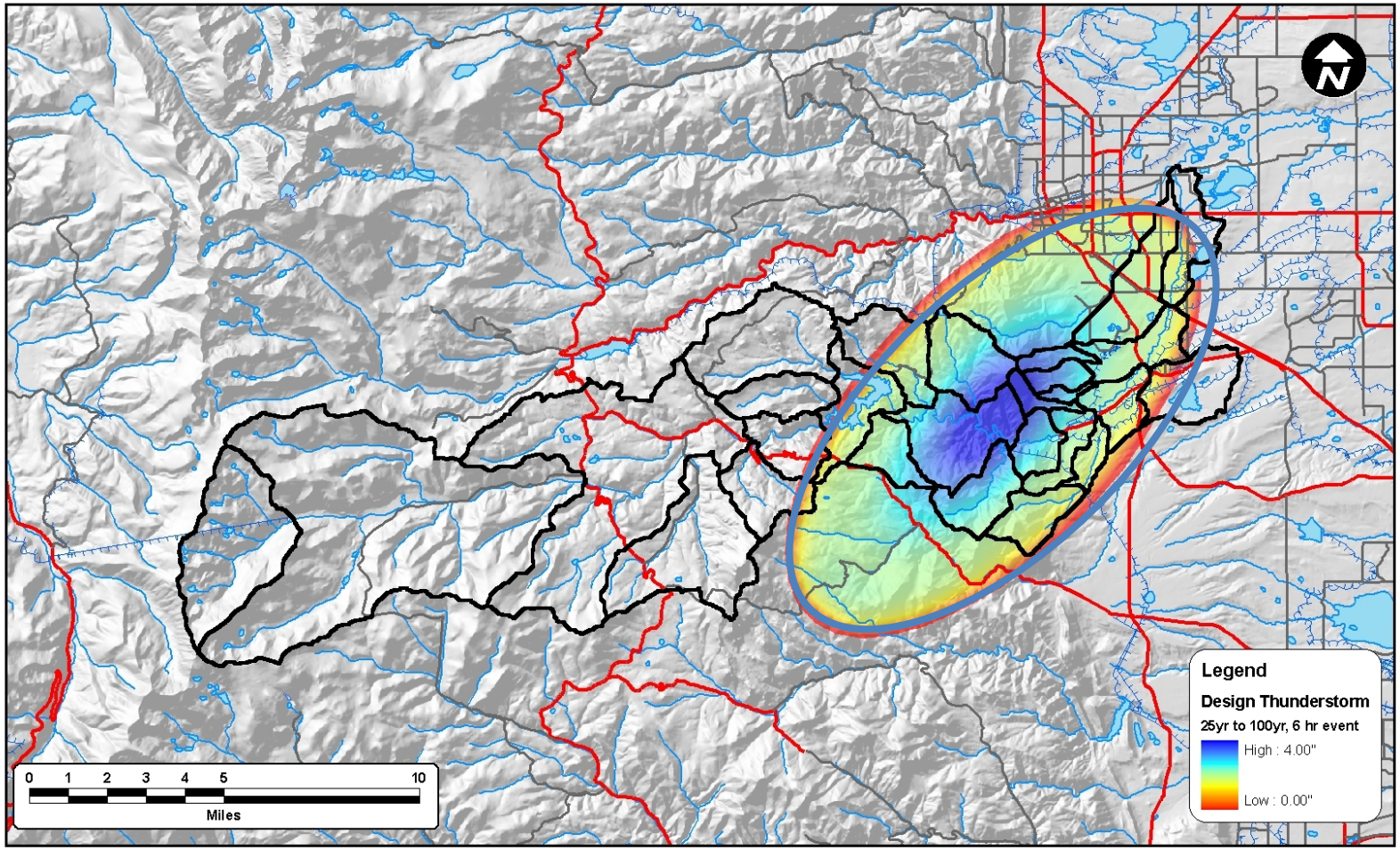




Fitted spatial characteristics into regulatory ellipses

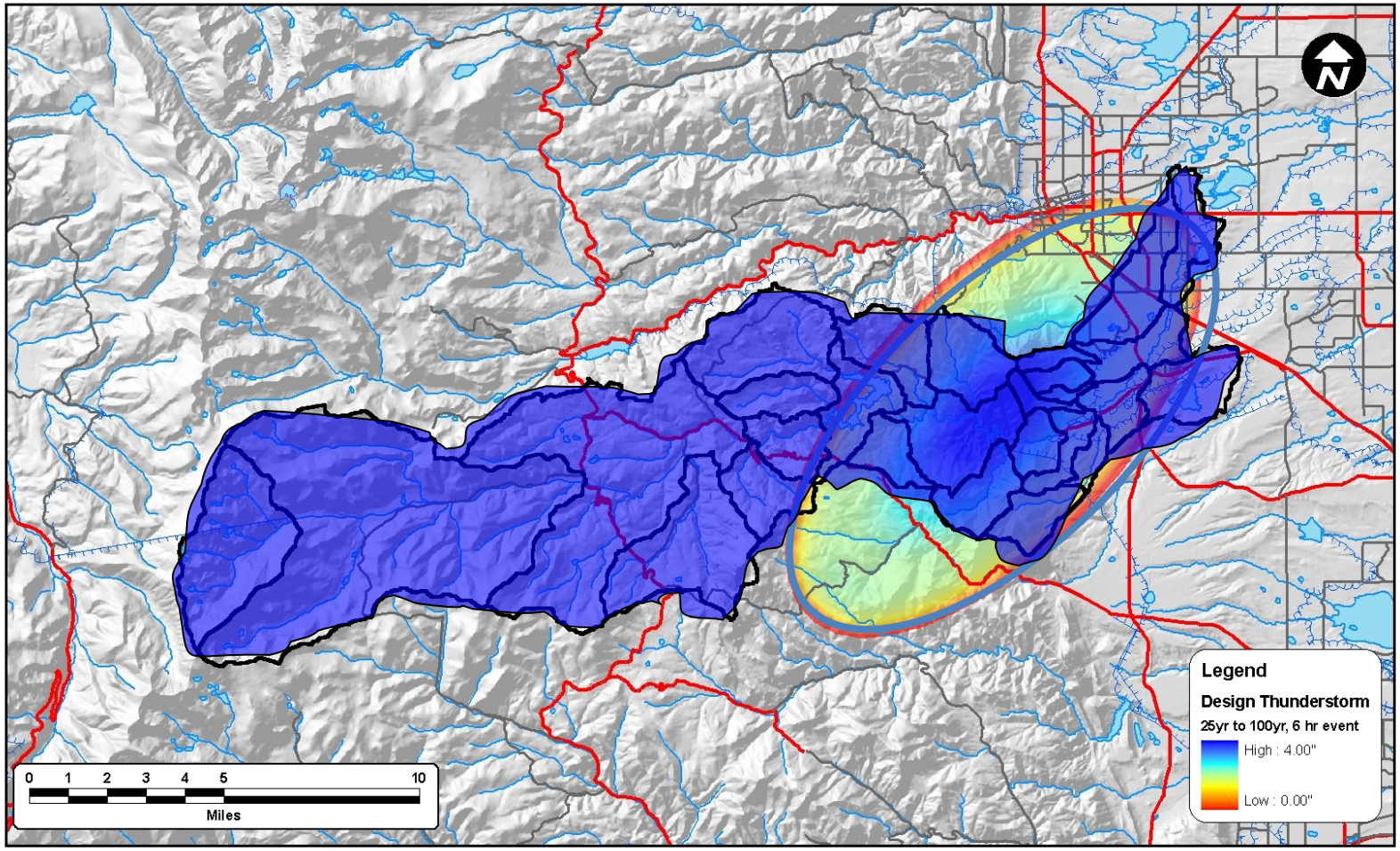
Used “radar-derived” storms to drive hydrologic modeling

6-hr, 25-yr to 100-yr, South Boulder Creek thunderstorm



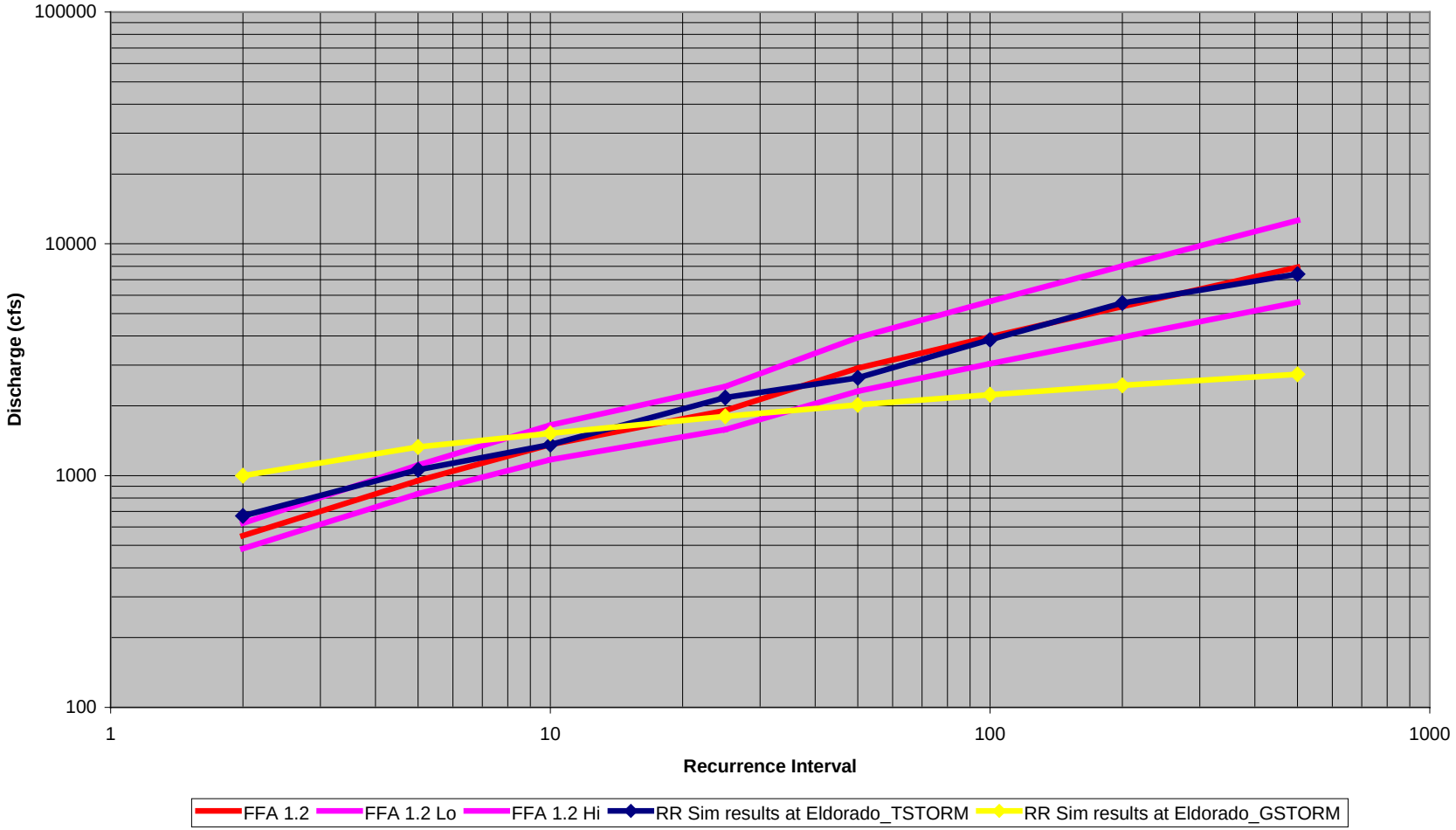
Dewberry

Design storm comparison: SDDS vs. old regulatory (blue)



Dewberry

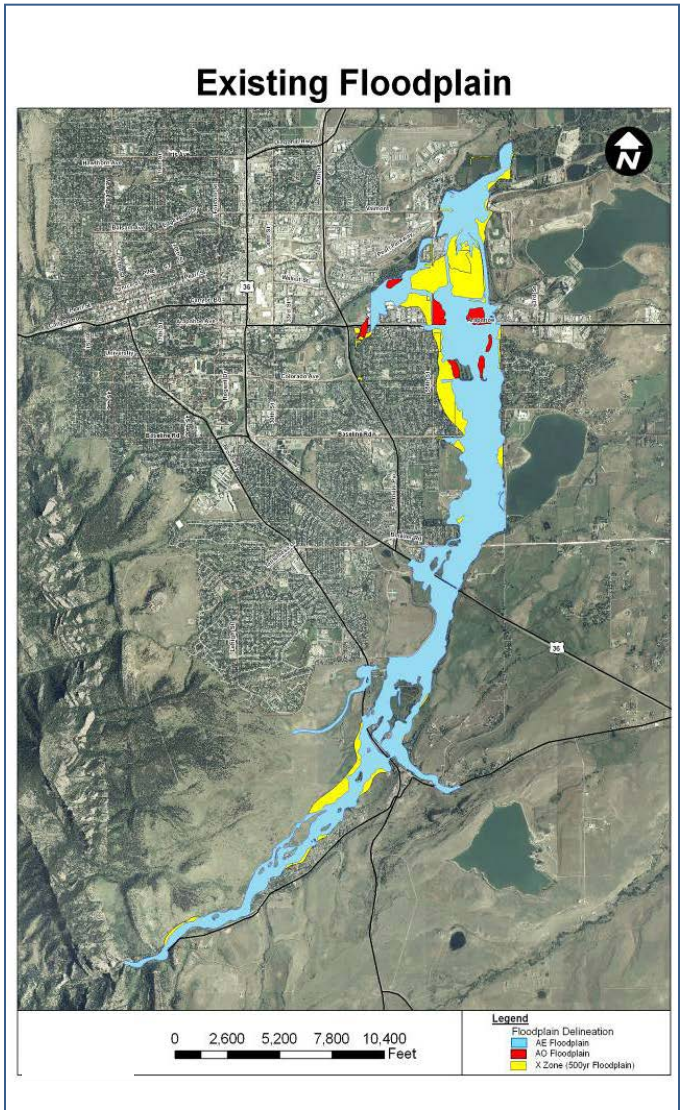
Comparison of radar design storm discharge for general storms (yellow) and thunder-storms (blue and magenta) to old standard



Updated 100-year Regulatory Floodplain

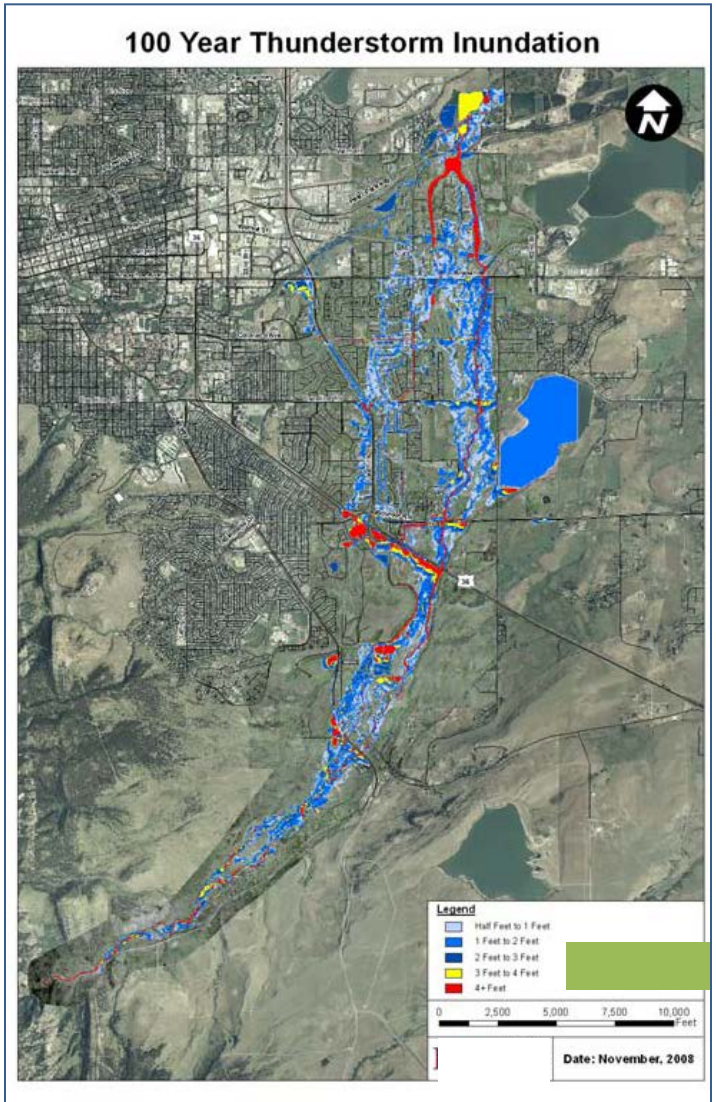
Before Study

Old floodplain



FEMA Accepted

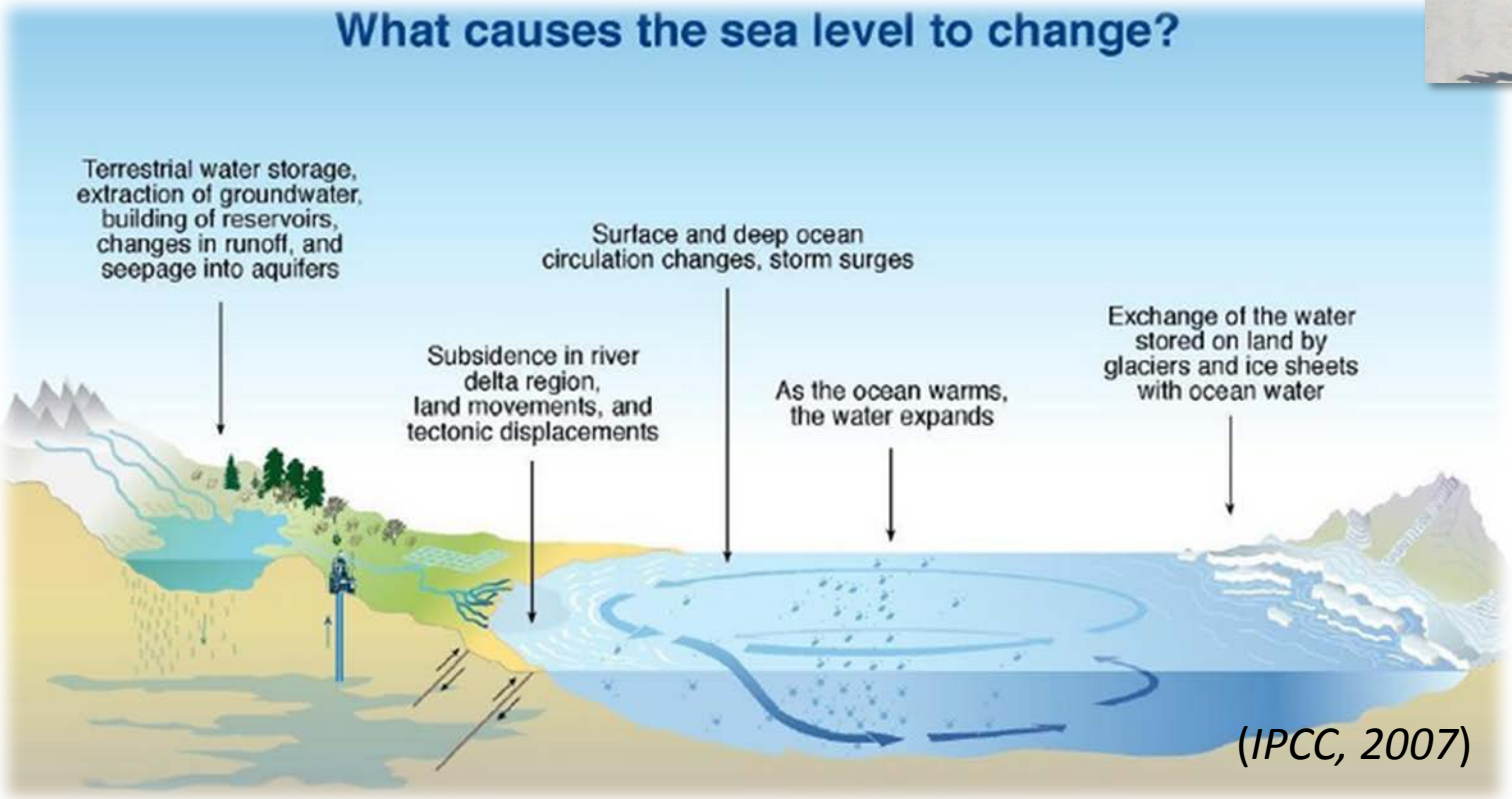
Updated floodplain



Coastal Community Sustainability – Measuring up to the Biggest Climate Change Challenge

1. Superstorm Sandy
2. Climate factors influencing changes in sea level rise and related high-impact weather events along coastal areas.
3. Are hurricanes and nor'easters increasing in frequency and intensity? Will storm surges continue to increase in magnitude?
4. How should risk assessment processes incorporate these changes?

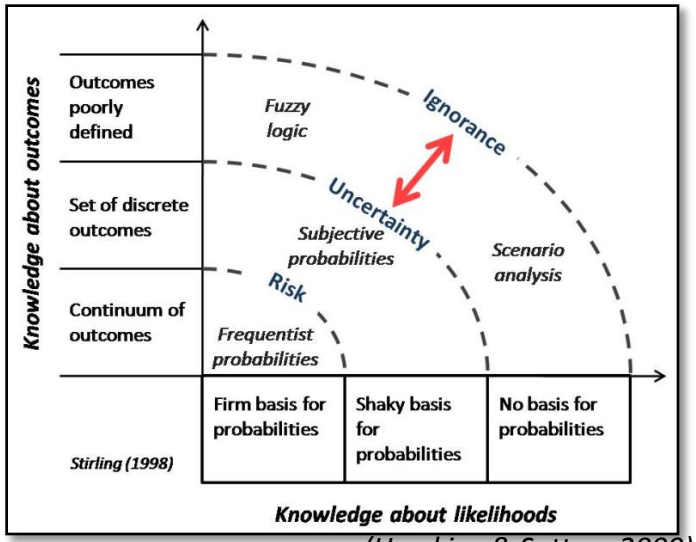
Sea Level Rise (SLR)



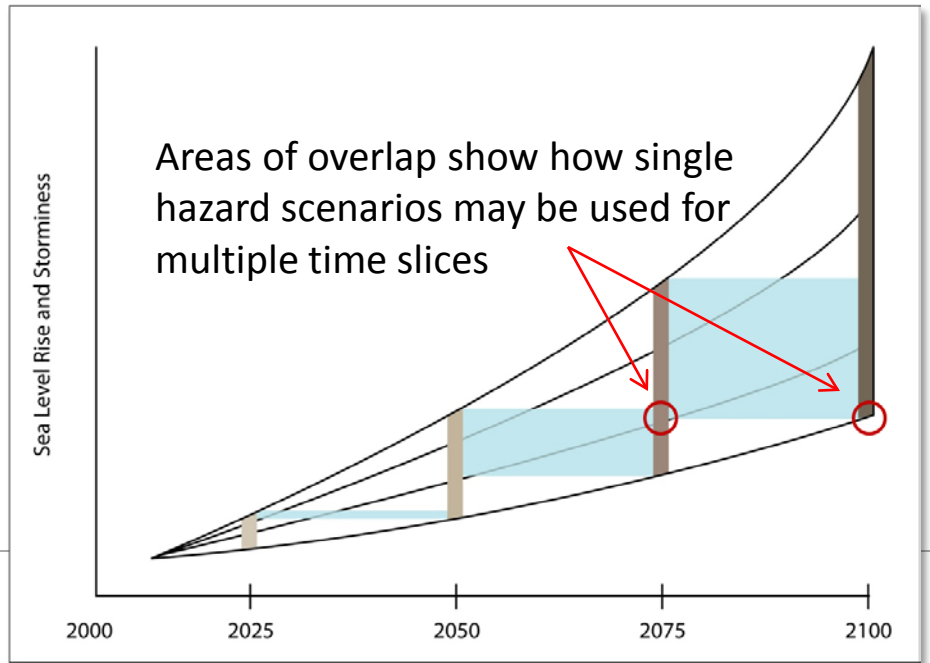
(*IPCC, 2007*)

- *Controversies in rate of SLR related to thermal expansion, melting of glaciers, and loss of ice uncertainties*
- *Small increase in sea level can have significant impact on coastal environments*

SLR Scenarios



(Hawkins & Sutton, 2009)



Approaches:

- Consult resource managers and stakeholders; consensus of near-term
- Scenario-based approach to address an uncertain future
- Select range of emission scenarios
- Tide gage, linear extrapolation
- USACE modified NRC SLR projections
- Low, Medium, High; acceleration rates

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Superstorm Sandy

- Are there direct links between Sandy and climate change?
- Hard to say, but certainly relation between climate and flood damage

•SLR of 12 in could give a typical 10-yr storm the intensity of the present 100-yr storm;

•High pressure ridge of air centered around Greenland that blocked the hurricane's normal out-to-sea path and steered it west toward land

•Cold front from the west that helped pull Sandy inland, and blast of Arctic air from the north

•Full moon and effect on driving high tides

•Waves commonly associated with large hurricanes, plus massive gale-force winds

Storms in Climate Context

- Warmer Arctic likely cause Greenland's ice sheet to melt -- buildup of heat in southern surface waters
- IPCC reports "low confidence" that humans affecting tropical cyclone patterns
- IPCC reports "likely" that tropical cyclones will get stronger, with faster winds and heavier rainfall with warmer temperatures. Overall number of hurricanes not likely to increase.

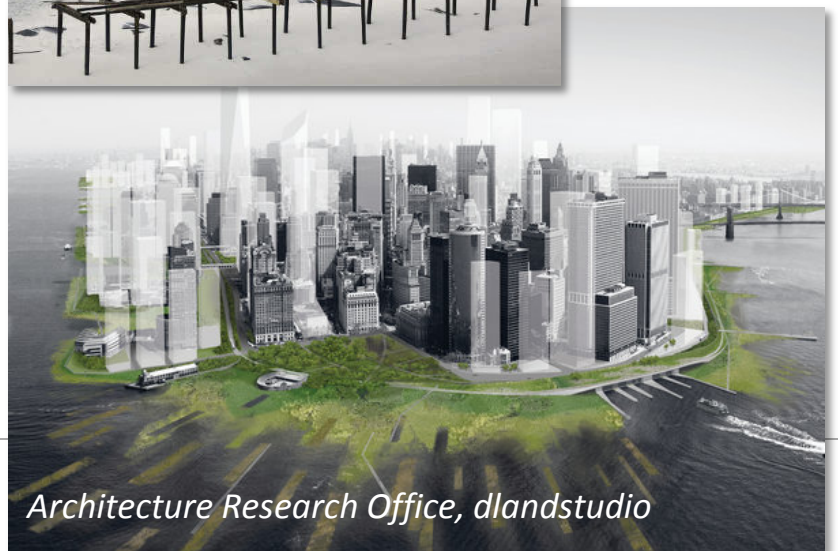
Boston specific:

- Greater extent and frequency of storm related flooding regardless if storm intensity remains steady
- Increase in daily tide heights
- Possible bi-monthly flooding due to astronomically high tides
- Storm surge reaches further inland, flood area previously not flooded

Storm Outcomes:

- Focus on climate change
- Emphasis on planning; pay now to prevent later damage costs
- Need to manage for risk

(NY Times, 2012)



Architecture Research Office, dlandstudio

Did Climate Change Cause Hurricane Sandy?

We Must Do More to Address Costs of Climate Change

…ks 'what if' a storm like Sandy hit Boston

UN climate scientist: Sandy no coincidence

Climate to guide New York reconstruction

Princeton researchers warn climate change will bring more big storms like Hurricane Sandy to N.J.

Most New Yorkers Think Climate Change Caused Hurricane, Poll Finds

Yes, Hurricane Sandy is a good reason to worry about climate change

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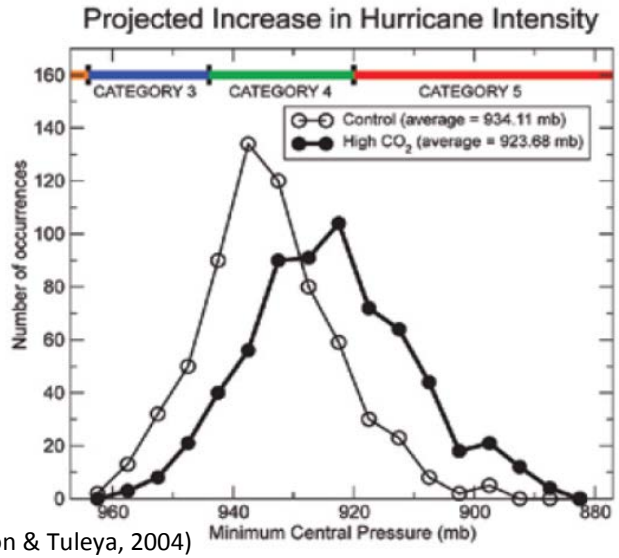
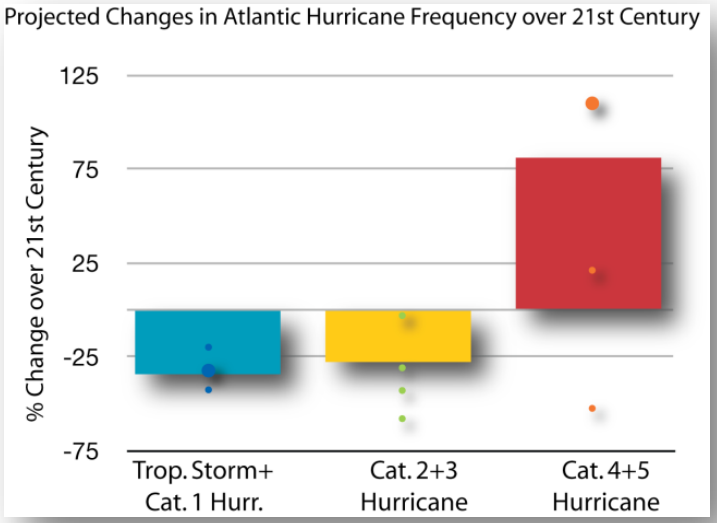
Examples of Storminess Scenarios



(Knutson & Tuleya, 2004)



- Re-analysis of landfall probabilities with Bender et al (2010) tropical storm climatologies
- Scenarios:
  - *Present Day Storm Characteristics*
  - *40% increase in Cat 4 & 5 storm frequency, 15% reduction in number of smaller storms (approx 2050 max)*
  - *90% increase in Cat 4 & 5 storm frequency, 33% reduction in number of smaller storms (approx 2100 max)*
- Implemented through changing parameters and weights in the Joint Probability Method statistical framework

Coastal Case Studies

- Source-Pathway-Receptor SLR Study (North Carolina)
- Transportation Impacts
- Risk communication and Web Viewers

Case Study 1: North Carolina Impact Assessment Study

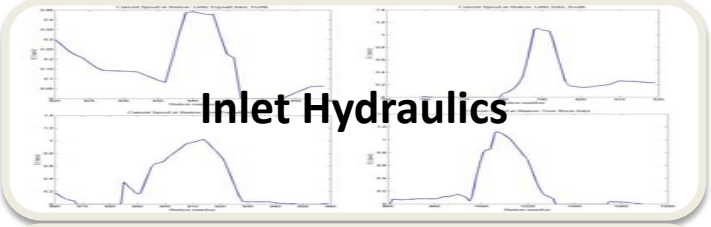
- Problem: No existing statewide, empirical financial impact assessment available for future flood losses due to SLR and no framework to calculate and track impacts due to changes in sea level.

- Scope:
  1. **Assess change in flood hazards for projected SLR scenarios**
  2. **Perform system-wide impact assessments of:**
     - **Permanent flooding (sea level rise)**
     - **Temporary Flooding (tides, surge, wave heights)**
     - **Annualized damages, 100 & 500-yr events, adjusted historical events**
  3. **Overlay hazards on living and built environments, scenarios of future development from 2025 to 2100 to assess impacts**
  4. **Analyze and identify cost effective consequence reduction strategies**

1. NC Geomorphic Evolution Process

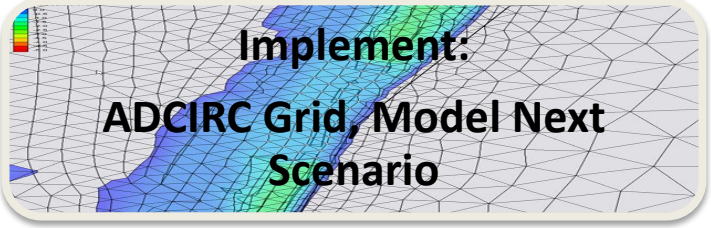
SLR Scenario Mean Higher
High Water Elevation (ADCIRC)

ID overtopping areas, relict features, enforce in model. Considers historical data (i.e.DCM erosion rates)



Tidal prism/cross-section/conveyance analysis, modify existing or add new inlets as needed

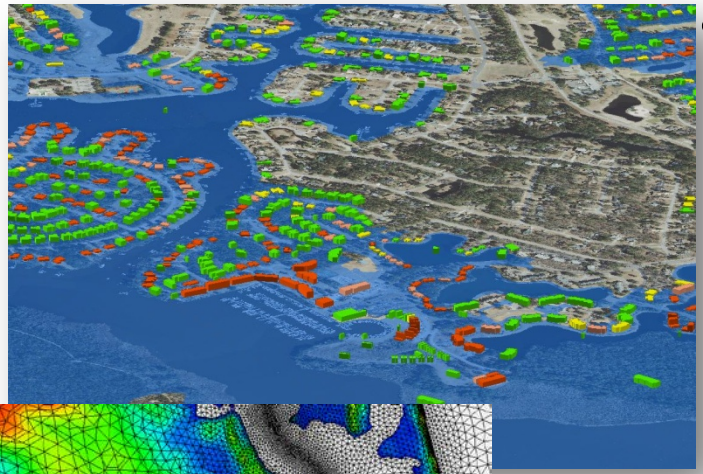
SLAMM 6.01, validation tested, ADCIRC inputs, subregion by fetch, tides, erosion rates

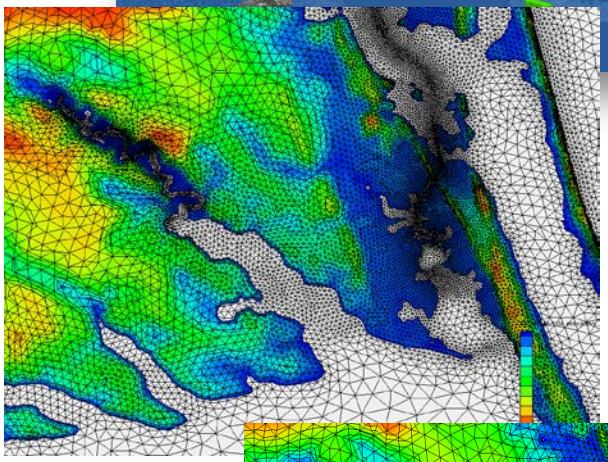


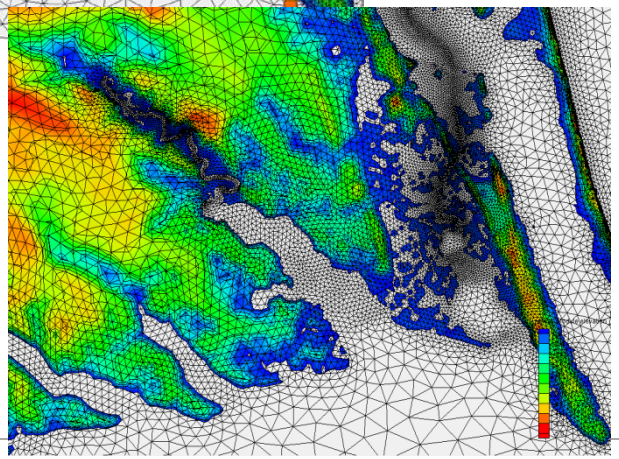
Overtopping enforcement, inlet cross-section, marsh elevation Change, land cover change

2. NC Risk Assessment

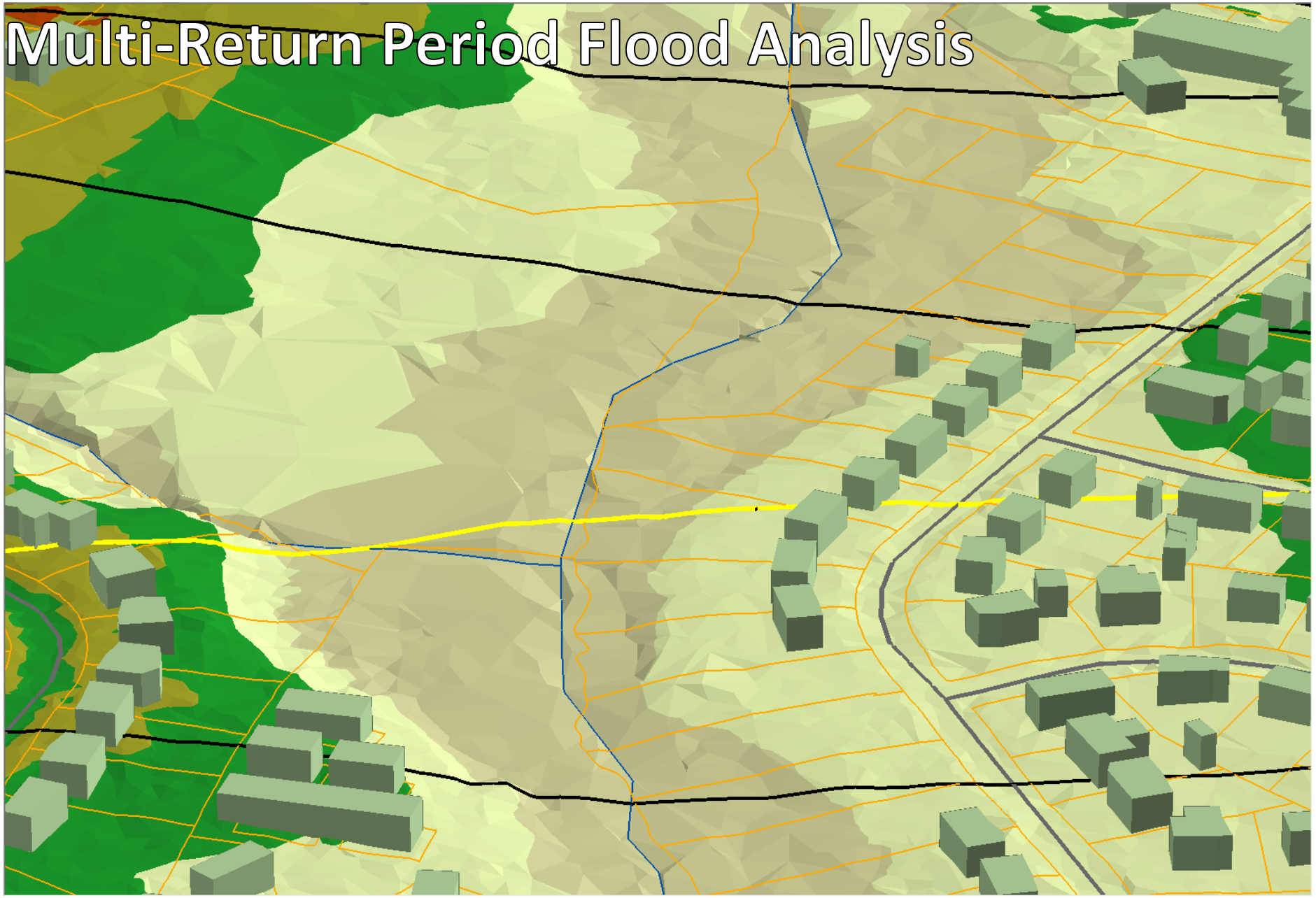
- Using hazard assessment products, identify impacts of SLR on the built environment.
  - Direct Losses to Structures
  - Critical Infrastructure / Key Resources
  - Indirect Losses
  - Transportation Impacts
  - Future Land Use and Development





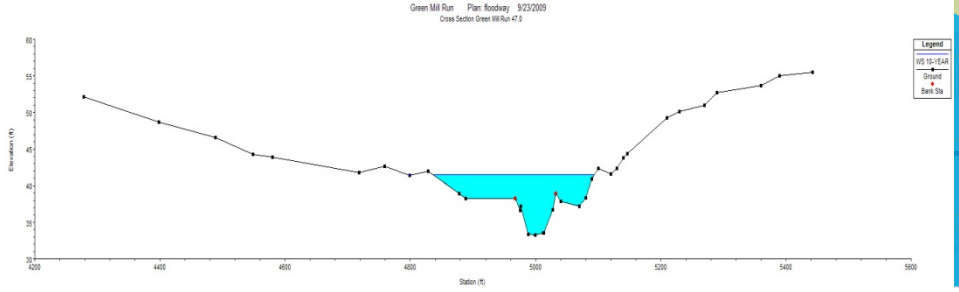


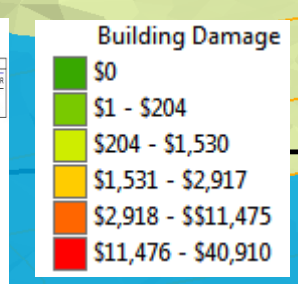
- **Land Loss Analysis:** summarized land lost to inundation and change in multi-frequency floodplains at the county level
- **Direct Losses:** Evaluate building information against depth grids, calculate losses using depth damage functions
  - ***Structure, contents, ALE, displacement days, relocation costs, lost income/wages/output/ rent/jobs***


Multi-Return Period Flood Analysis

Multi-Return Period Flood Analysis

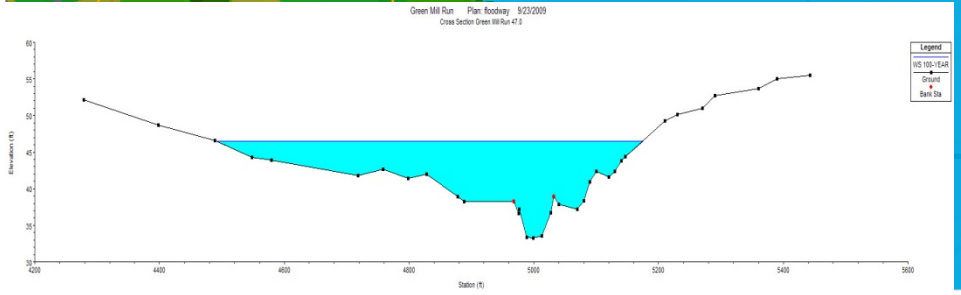
Damaged Buildings
10 Year Flood
Total Loss = $59,965

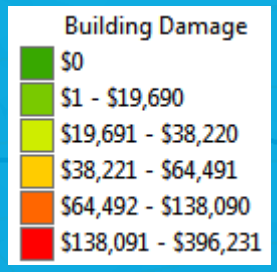




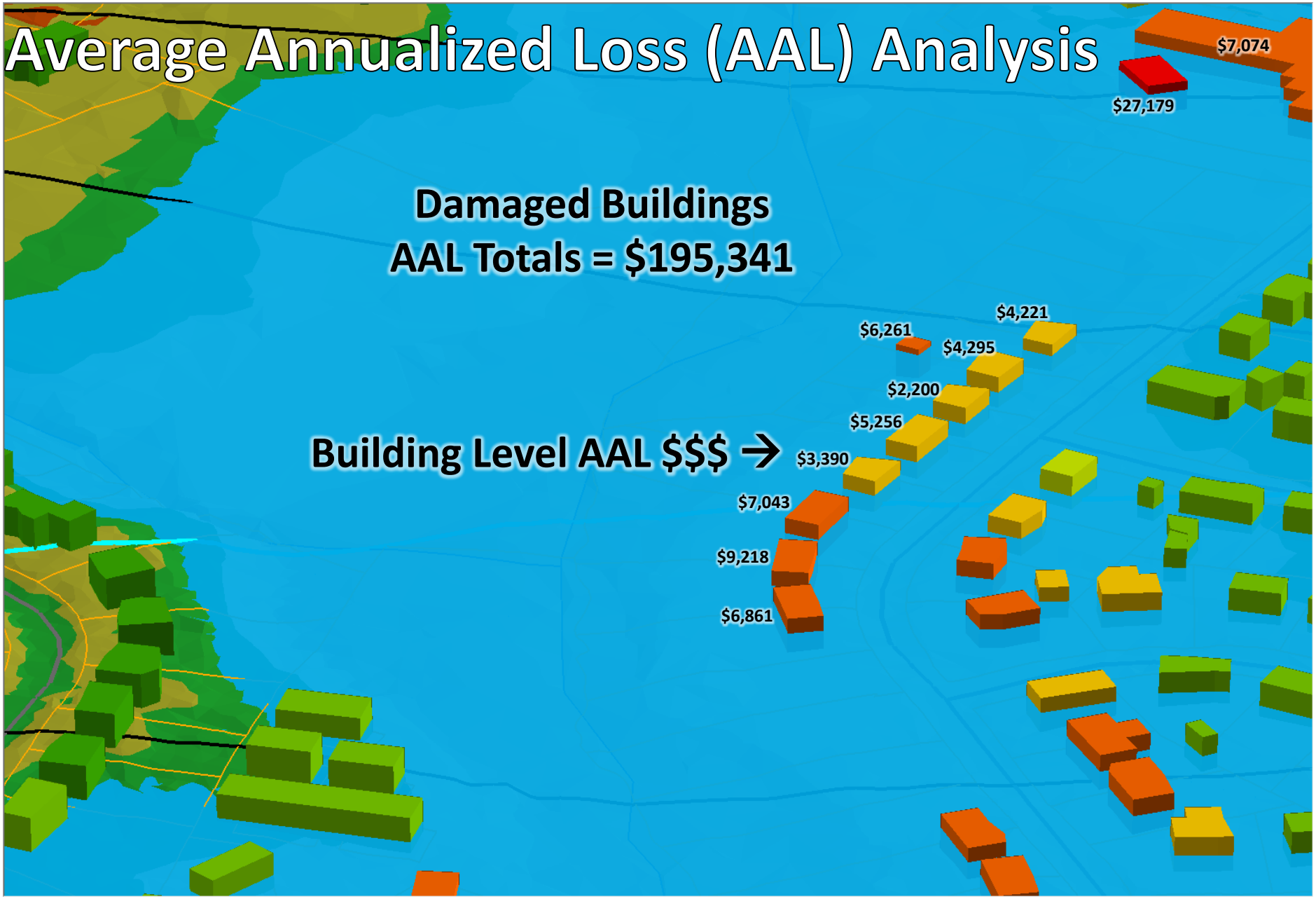
Multi-Return Period Flood Analysis

Damaged Buildings
100 Year Flood
Total Loss = $2,433,3310





Average Annualized Loss (AAL) Analysis



What does this mean for atmospheric sciences?

- As the country re-develops its energy, water and transportation infra-structure meteorologists have a significant role to play.
- Engineering companies will need skilled meteorologists with multi-talents.
- Basic and applied research needed for coastal areas, extreme weather events (heat waves to tornadoes to floods to hurricanes).
- Weather forecasting is poised to change.

What are the talents needed?

- Meteorological ***modelers*** from the climate scale to the miso-scale. These modelers need to be able to use model output to drive decision support systems that connect to other models.
- Need multi-degreed meteorologists: m-engineers, m-hydrologists, m-economists, m-health, m-communicators, m-policy, m-gis programmers, m-emergency preparedness, climatologists – etc all the above.

QUESTIONS

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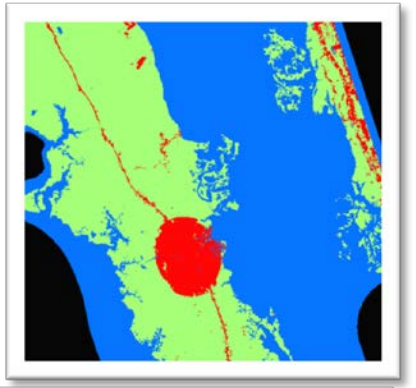
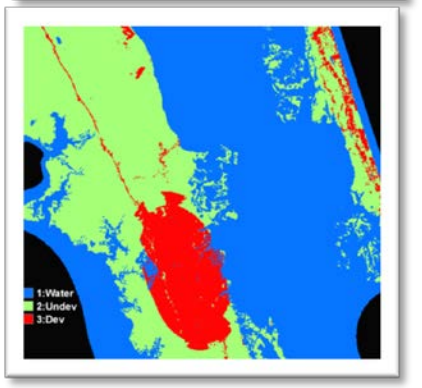
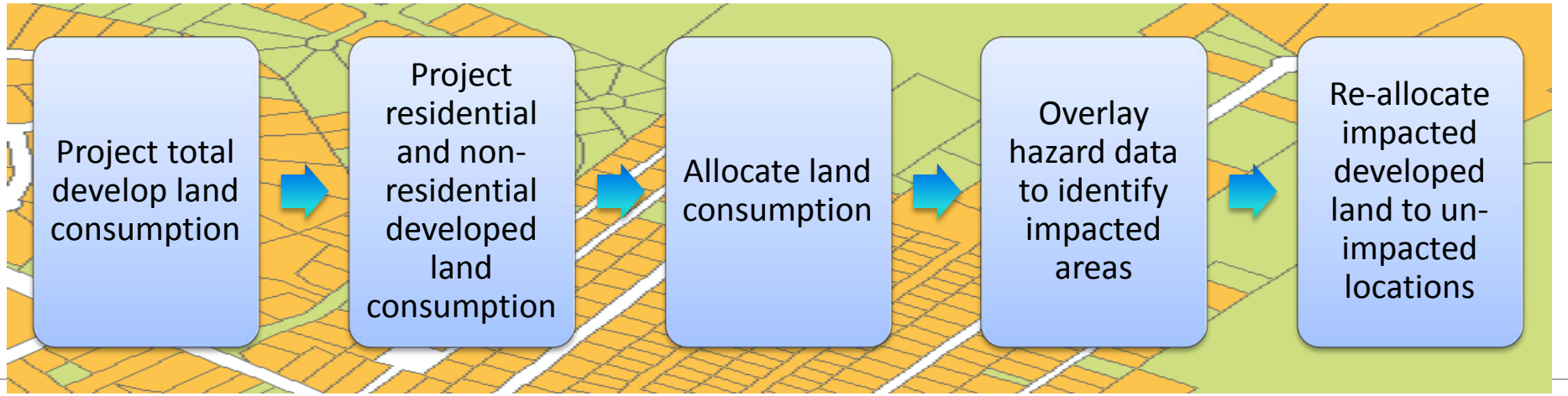
3. Land Use Scenarios

- **Defines projected future built environment**
  - *Multi-criteria land use model*
  - *Helps prevent overestimation of impacts by removing previously impacted structures from financial analysis*
  - *Based on historical trends, economic projections*
  - *State and EPA cohort component model used*

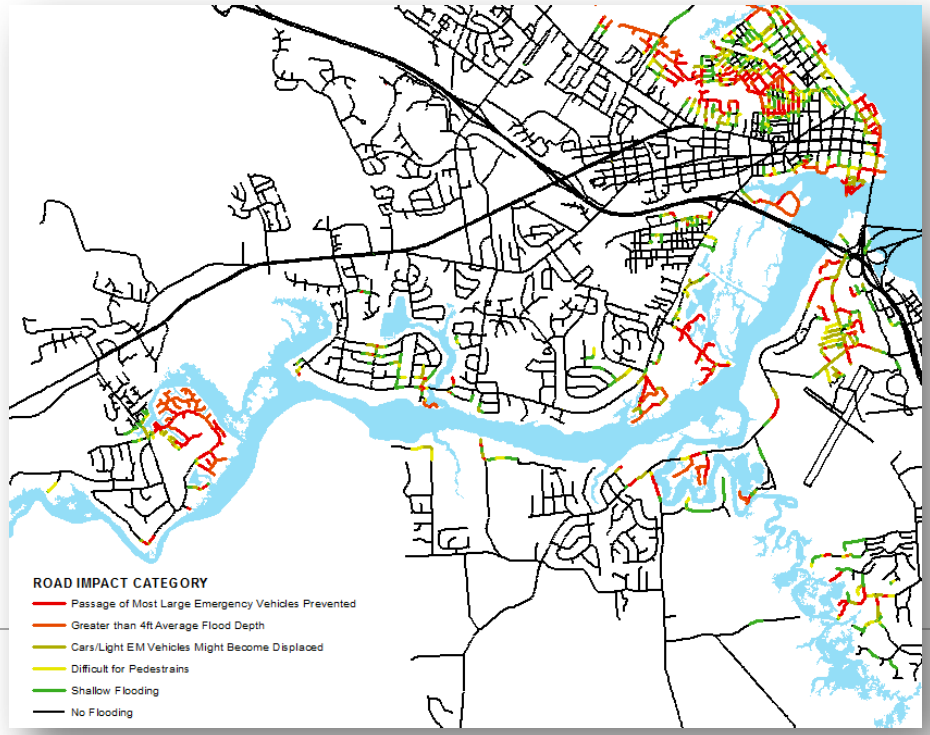






Case Study 2: Climate Change Impacts to Transportation Assets

- Mobile terrestrial LiDAR data and aerial LiDAR to form countywide DEM of roadway surfaces
- Roadway DEM subtracted from flood depth grids to create individual road depth grids for each



- Road segments classified according to hazard to pedestrians, vehicles, and emergency vehicles

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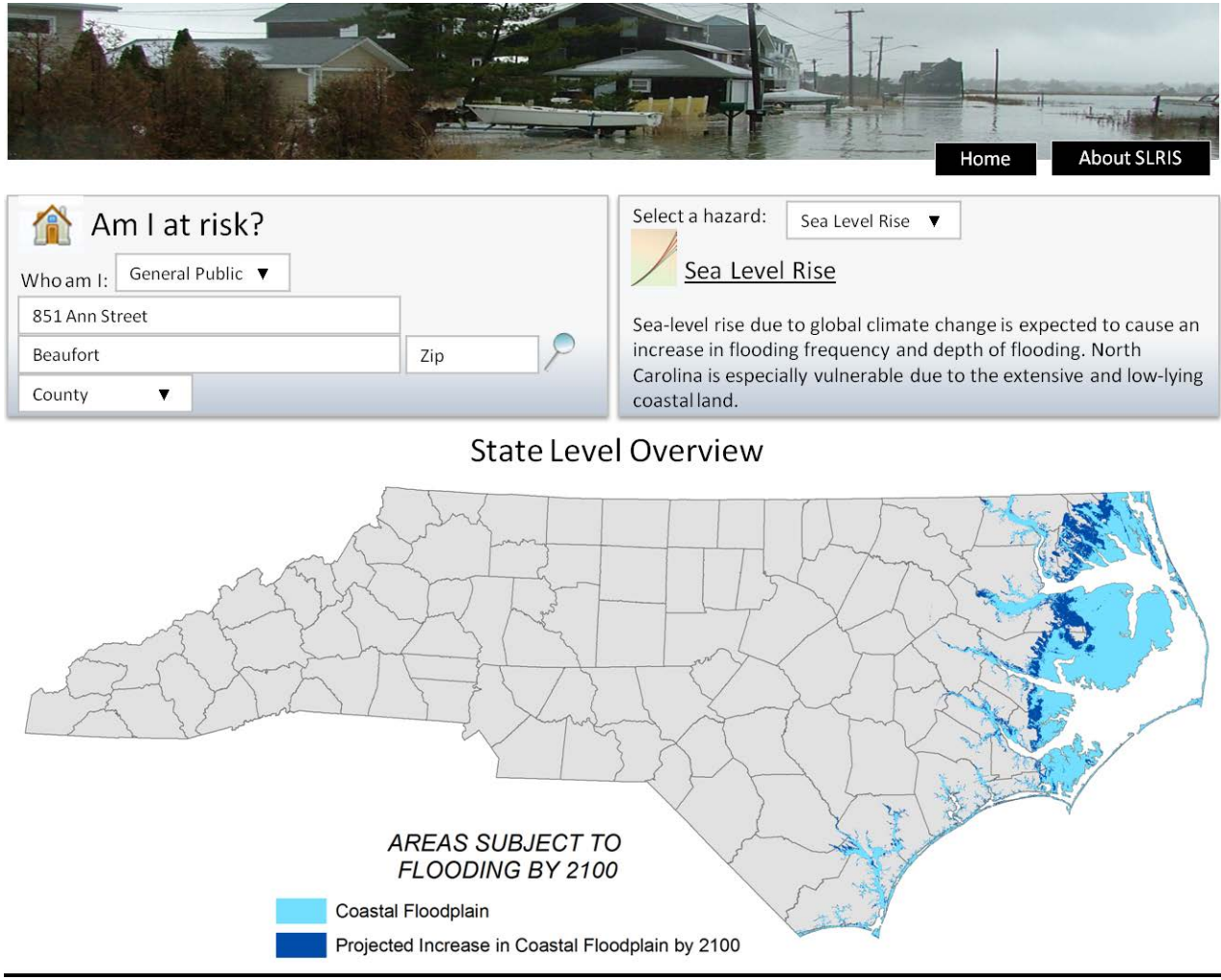
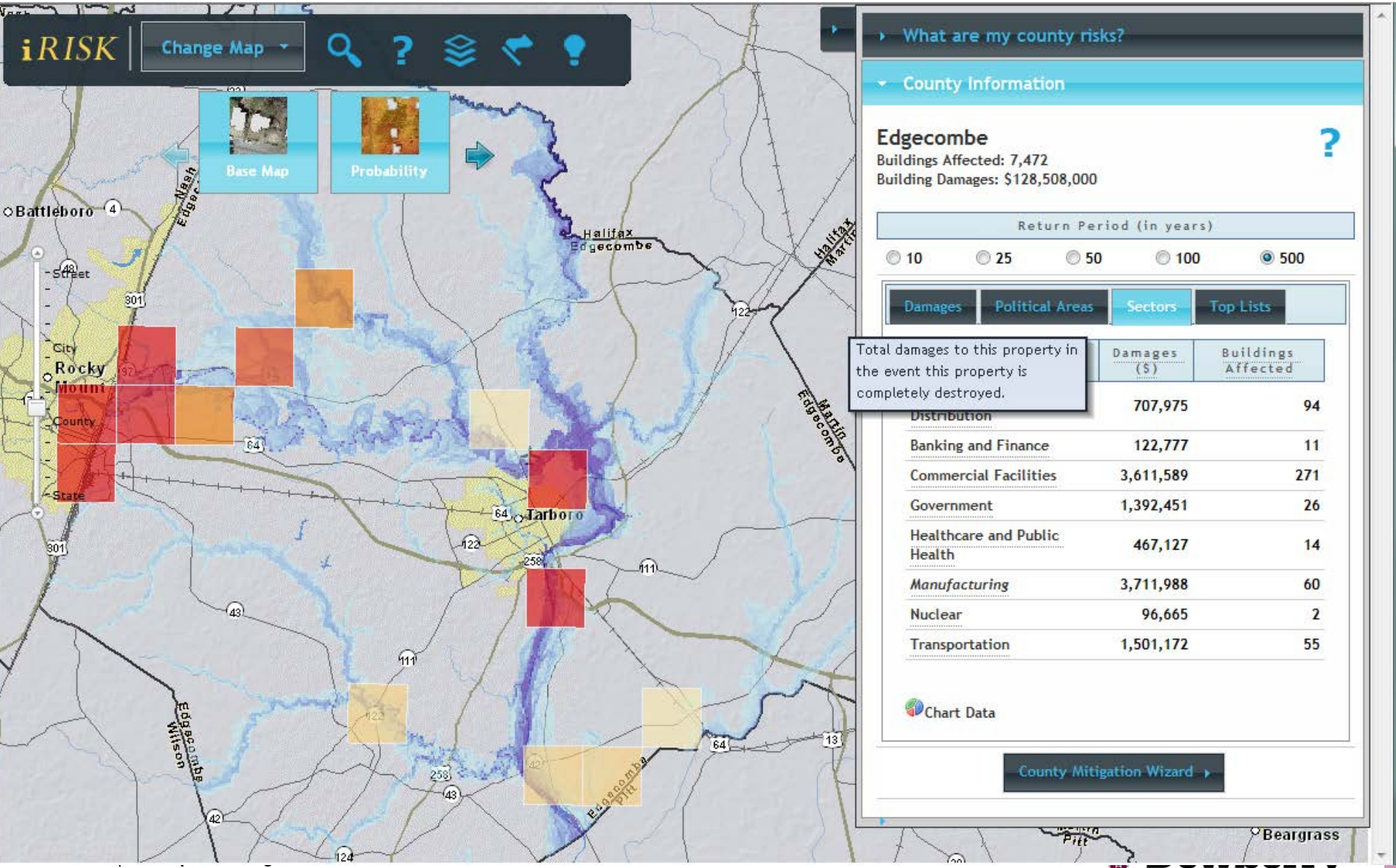
Case Study 3: Coastal Web Viewers

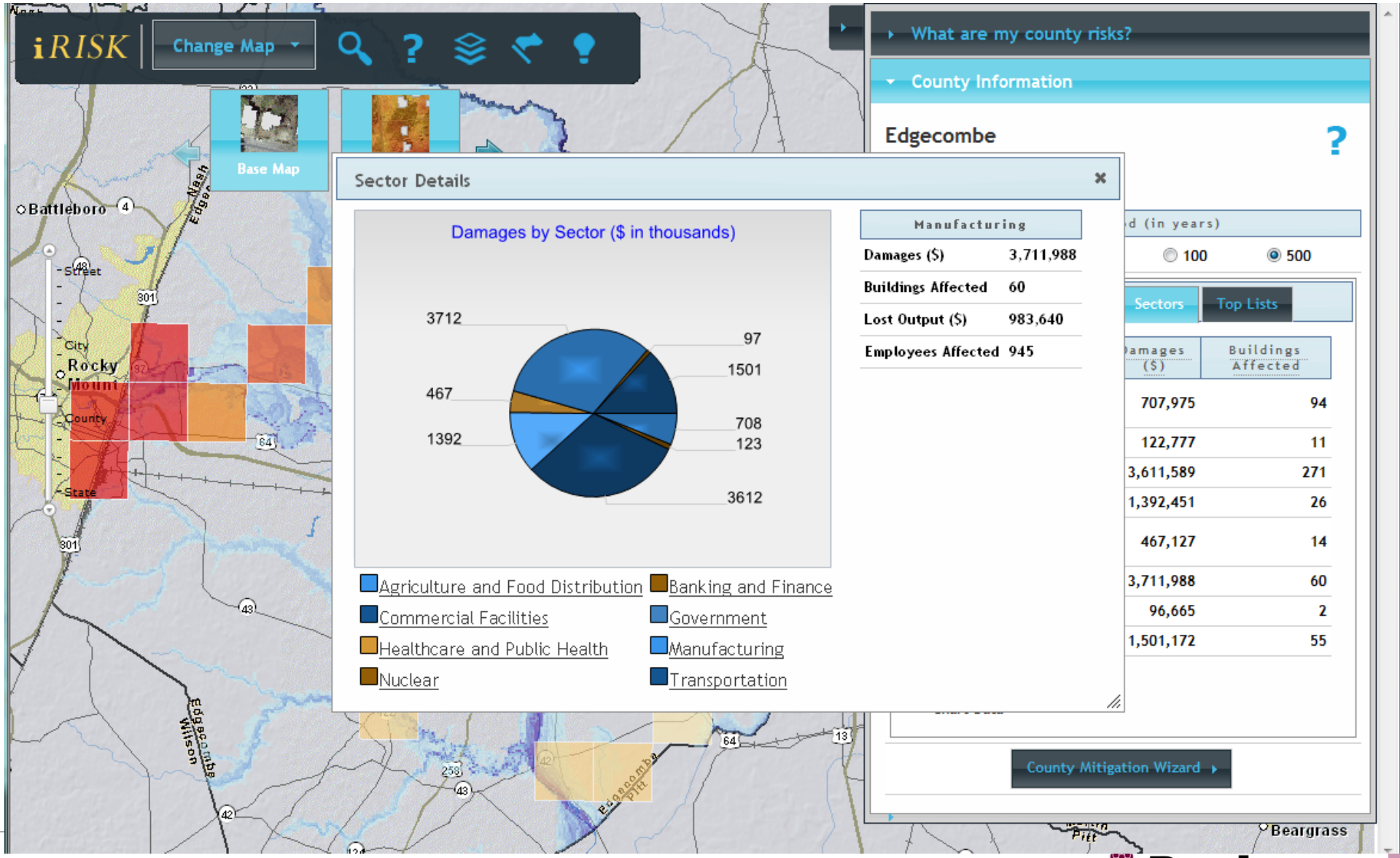
1. iRISK Viewer



iRISK – Sector Hot Spots (Manufacturing)



iRISK – Overall Sector Charts/Details



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2. Community Adaptation to Sea-Level Rise and Inundation (CASI)

- Objective: Advance research into how the combination of deliberative polling and local impacts data visualizations can increase public engagement in evaluation of policy responses to sea level rise
- Exposure and risk analysis to permanent inundation and coastal flooding at the building level
- Google site based easy-to-use portal

Step 1: Find a Location

Search by Street Address or Use the Map to Find a Location:

Search Address | Clear Address

Address for Point of Interest (Approximate):
3402 Chesapeake Walk, Annapolis, MD 21403, USA

Step 2: Choose a Scenario and Year

Choose Scenario *(Find out more)*:

- Historic Trend
- Low Acceleration
- Moderate Acceleration

Choose Year:

- 2012
- 2025
- 2050
- 2075
- 2100

Address Search Result
Permanent Inundation
1 % Chance Floodplain
Low Composite Risk Exposure
Medium Composite Risk Exposure
High Composite Risk Exposure
Impacted Neighborhoods
Selected Feature(s)

Step 3: View Summary of Estimated Impacts

Reset ALL

Building | Neighborhood | County

Building Summary

Composite Risk Analysis Category:
Low

Year	Exposed to 1% Annual Chance Floodplain?	Expected Damage During 1% Annual Chance Flood	Percent Chance of Coastal Flooding in a 30-Year Period	Permanent Inundation at this Sea Level Rise Scenario?
2012	NO	No Damage	0%	NO
2025	NO	No Damage	6%	NO
2050	YES	No Damage	6%	NO
2075	YES	Minor	26%	NO
2100	YES	Minor	46%	NO

Climate change planning horizons

- Update design data base.
- Consider HCI trends.
- Innovative design storms

- Paleo-trend analyses
- Natural variability (NV) trend analyses
- Consider GCM

- GCM scenarios
- Down-scaled statistical or dynamical
- NV trend analyses

0-30 years	30-50 years	50-100 years

Planned life cycle of infra-structure

Intelligent Phased Adaptation of Design to Climate Change

Henz, EOSH Conference 2009

- Initial design to 25-yr climate change impact.
- At 20-yr point, re-assess climate design impacts to 50-yr impact.
- At 40-yr point, re-assess climate design impacts to 100-yr impact.