NOAA's Hydrometeorology Testbed (HMT)

American River Basin, NOAA Perspective

8th Annual Climate Prediction Applications Science Workshop
Managing Water Resources and Drought in a Changing Climate

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Outline

I. Overview of HMT & Linkages to Climate
  - Physical Processes and Observations

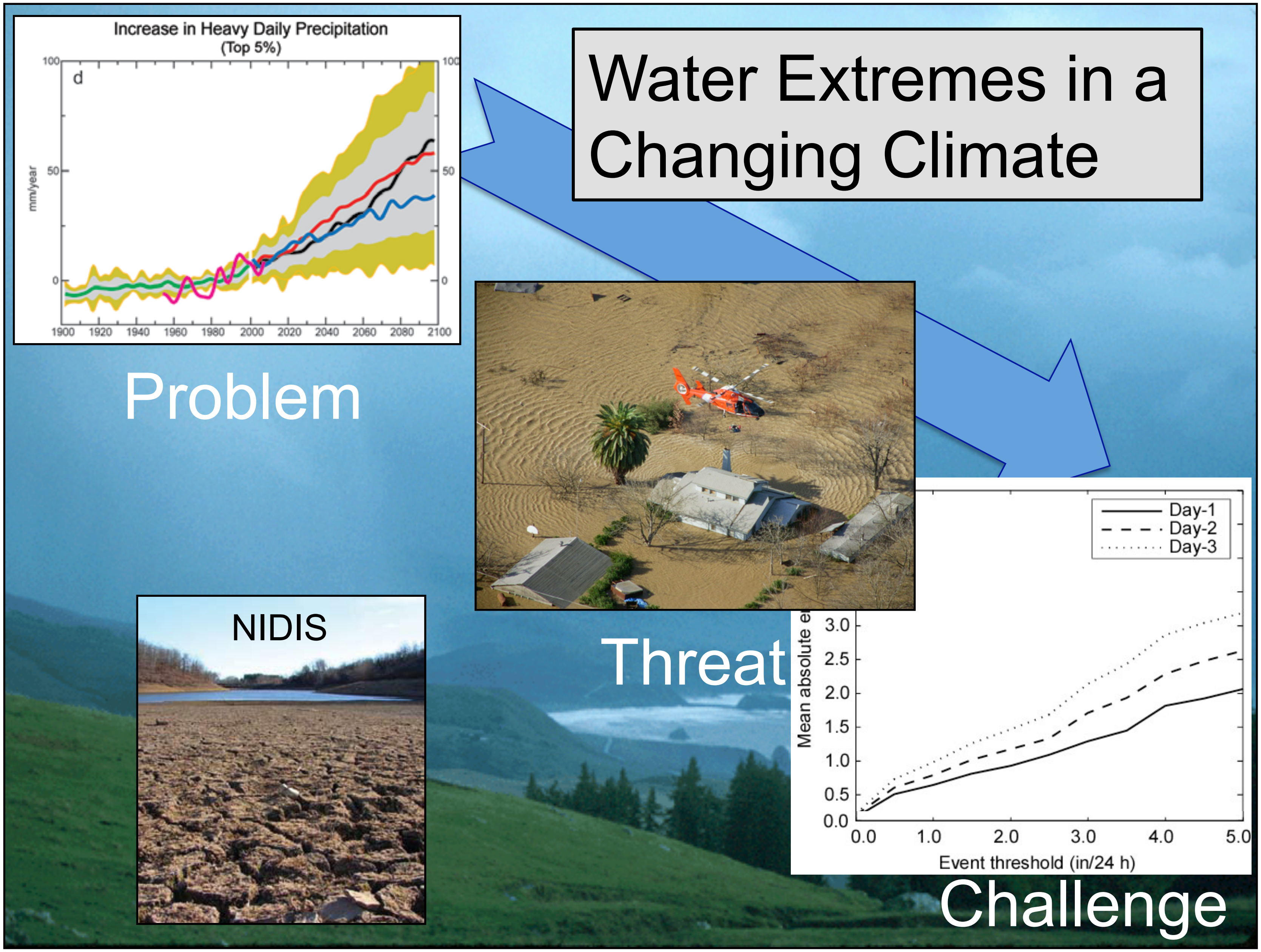
II. Example: Soil Moisture

III. Example: Atmospheric Rivers

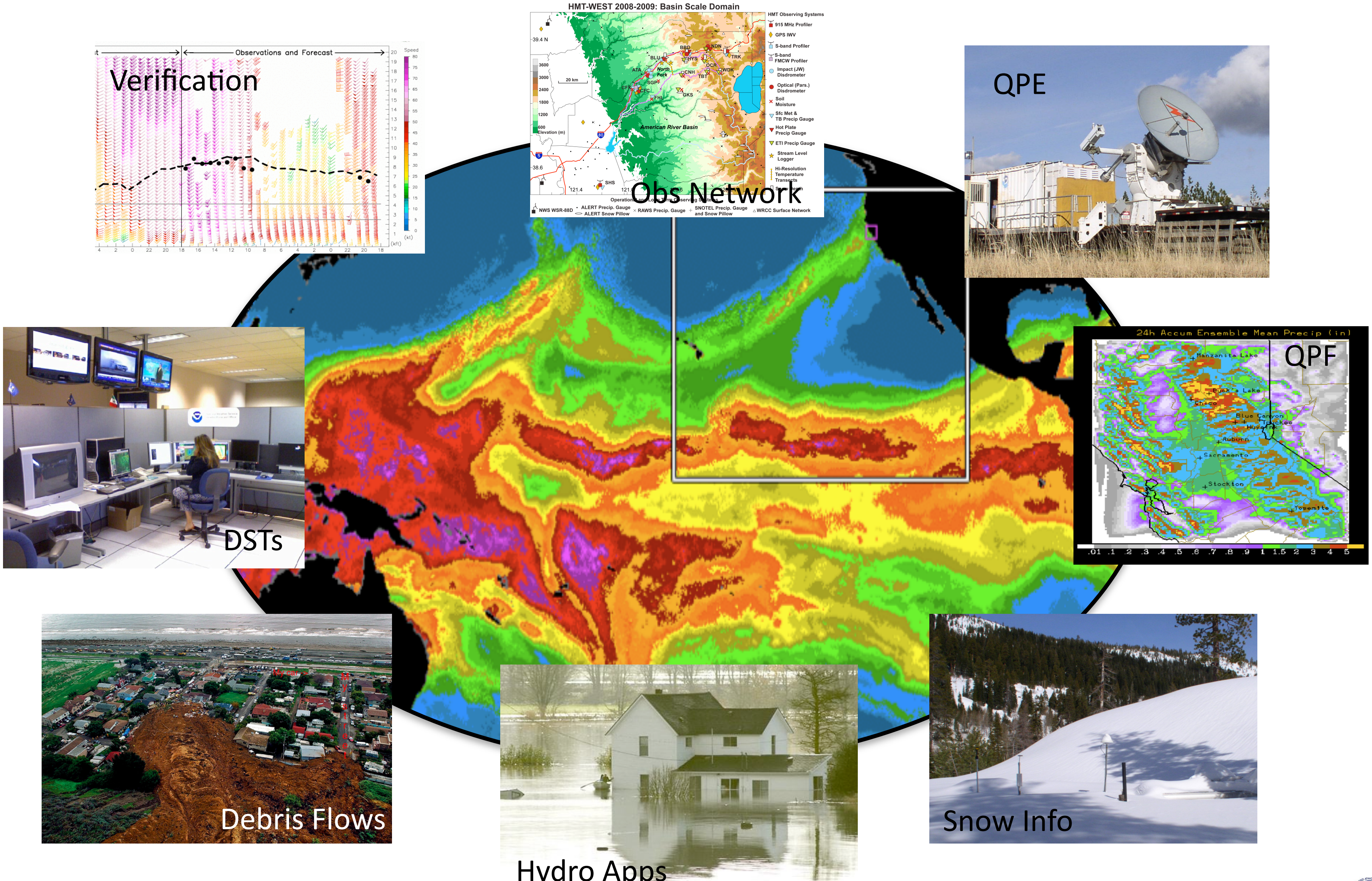
Water and a Changing Climate...

"Within the United States, extensive climate-related changes have been documented over the last century. These include increases in continental-average temperatures, rising sea levels in many coastal locations, an increased frequency of extreme heavy rainfall events, lengthening of the growing season, earlier snowmelt, and altered river flow volumes. Water is an issue in every region, but the nature of the potential impact varies. Drought is a serious problem in many regions, especially in the West and Southeast; and floods and water quality problems are likely to be amplified by climate change in most regions."

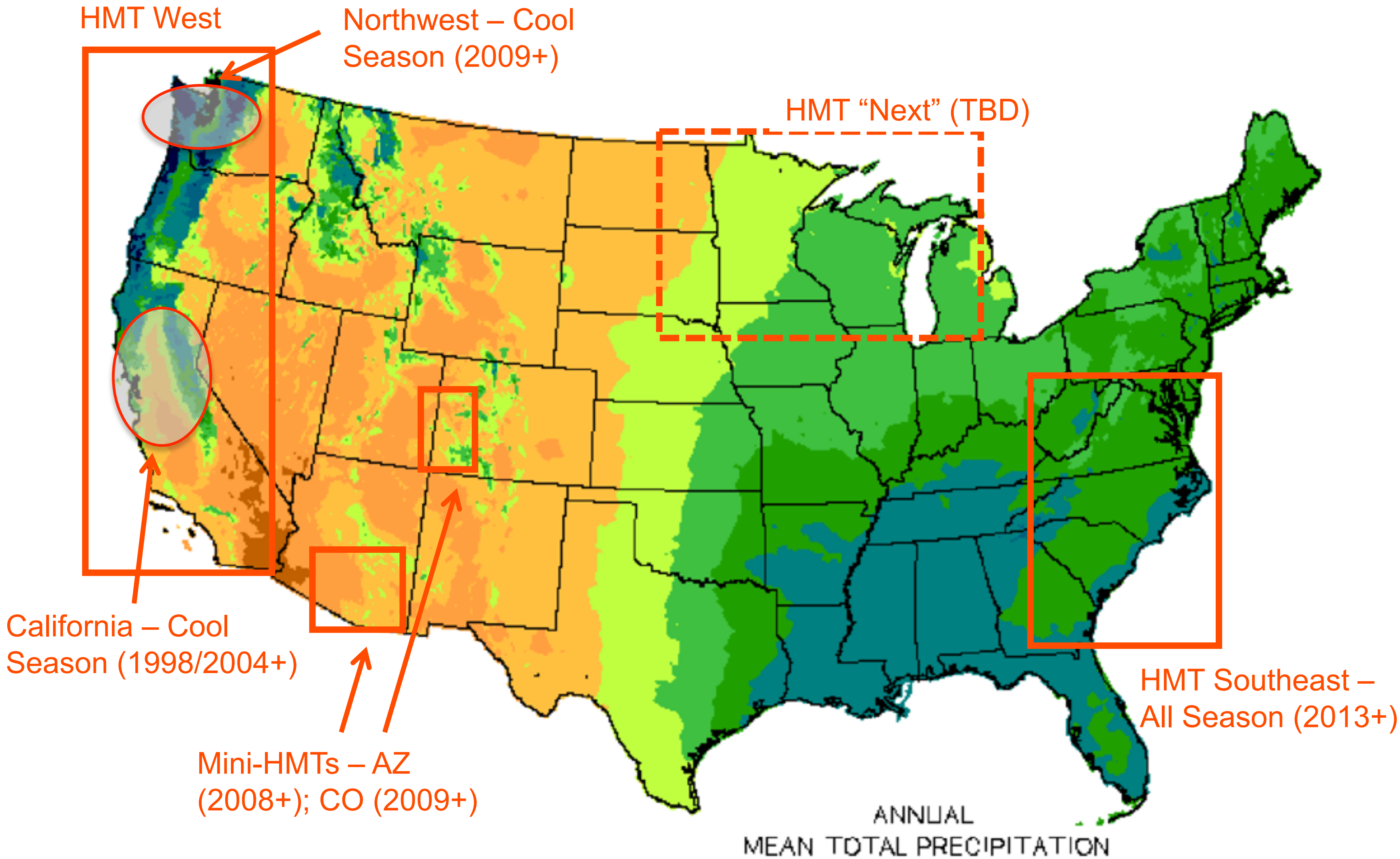
– Dr. Jane Lubchenco, NOAA Administrator


Water Extremes in a Changing Climate
Increase in Heavy Daily Precipitation
(Top 5%)
d
mm/year
100
50
0
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Problem
NIDIS
Threat
Day-1
Day-2
Day-3
Mean absolute e
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
1.0
2.0
3.0
4.0
5.0
Event threshold (in/24 h)
Challenge

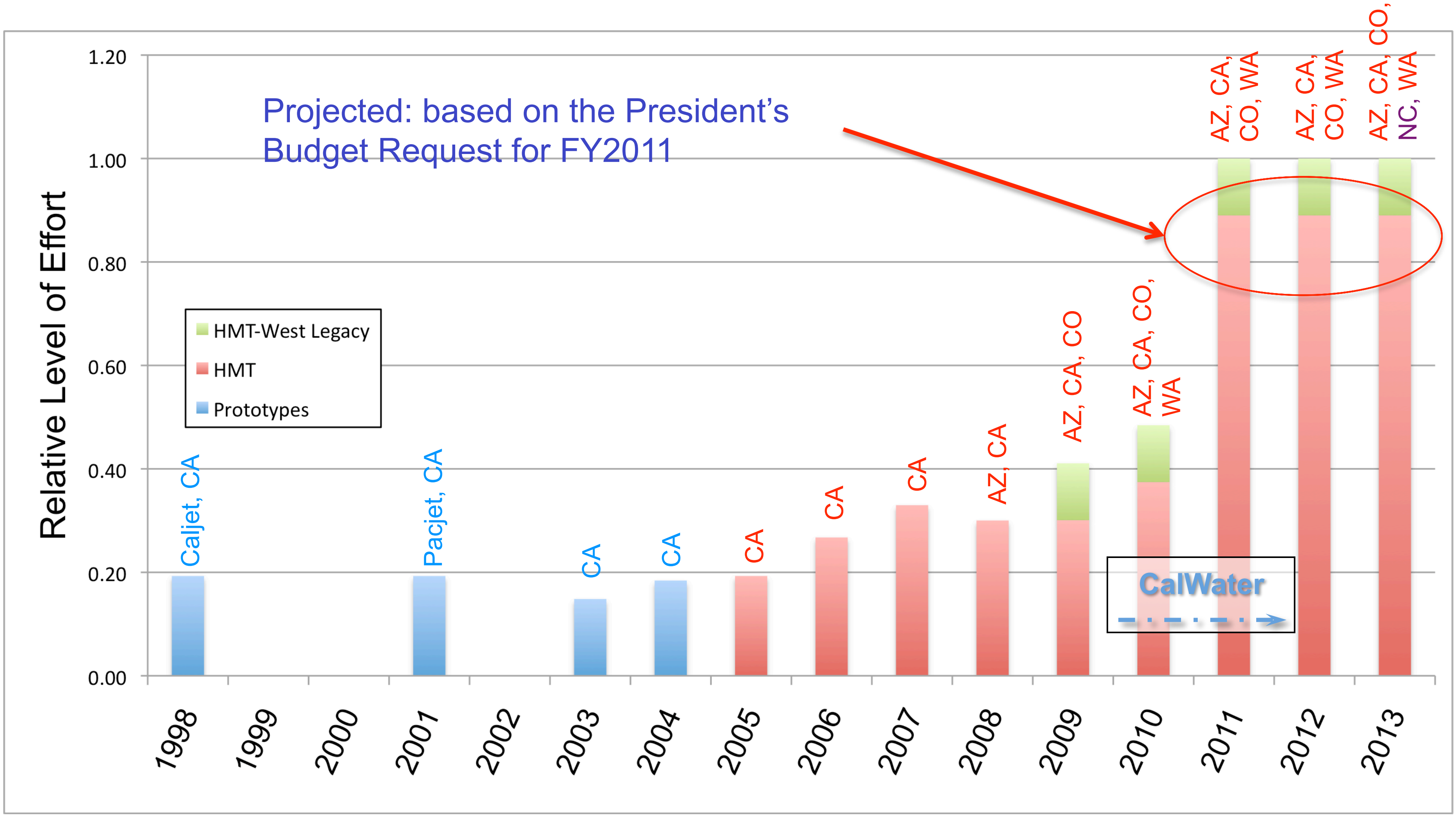
Response: HMT's Major Activity Areas



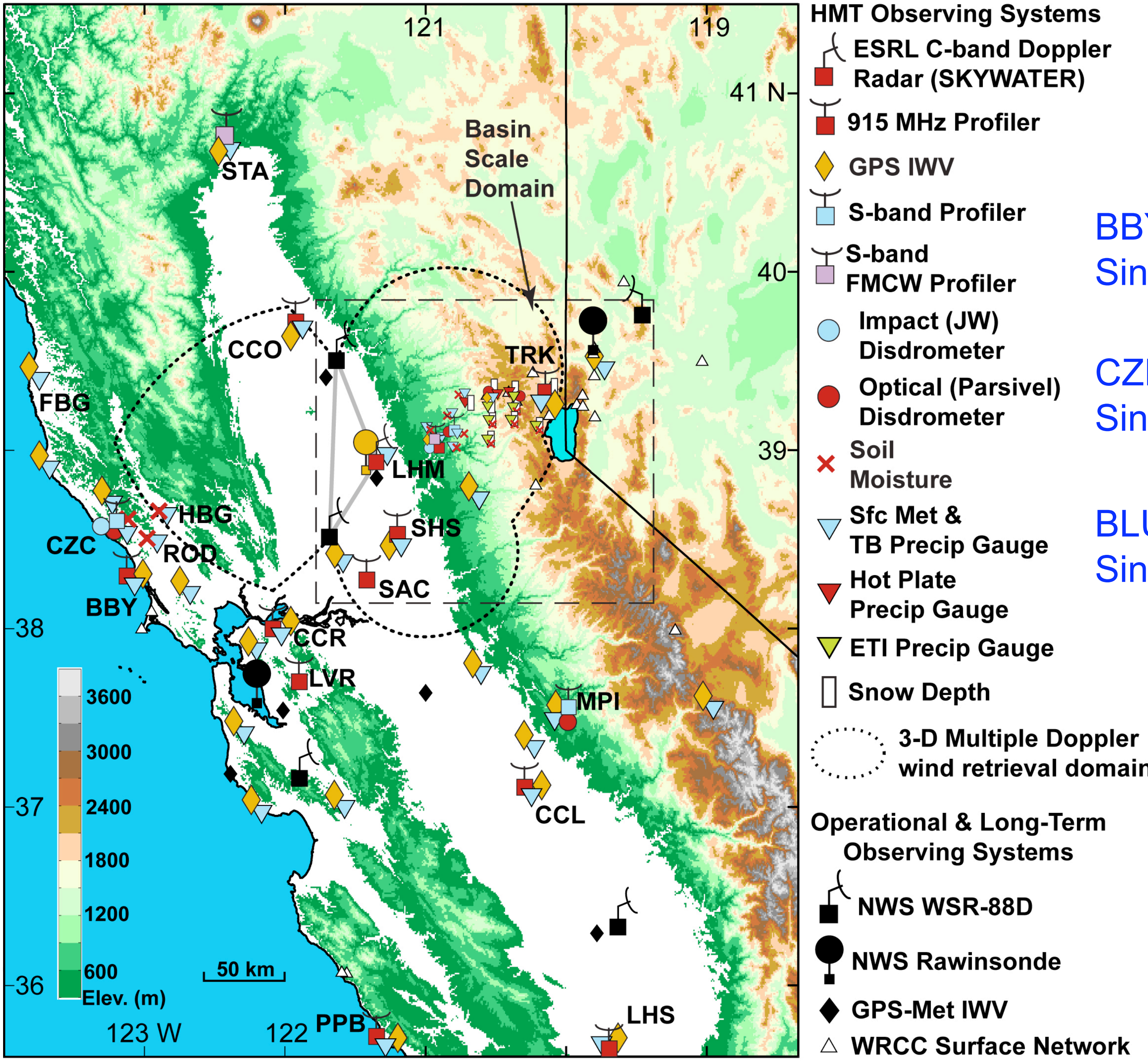
A National Testbed Strategy



Timeline & Overall Effort



HMT-WEST 2010: Regional Scale Domain

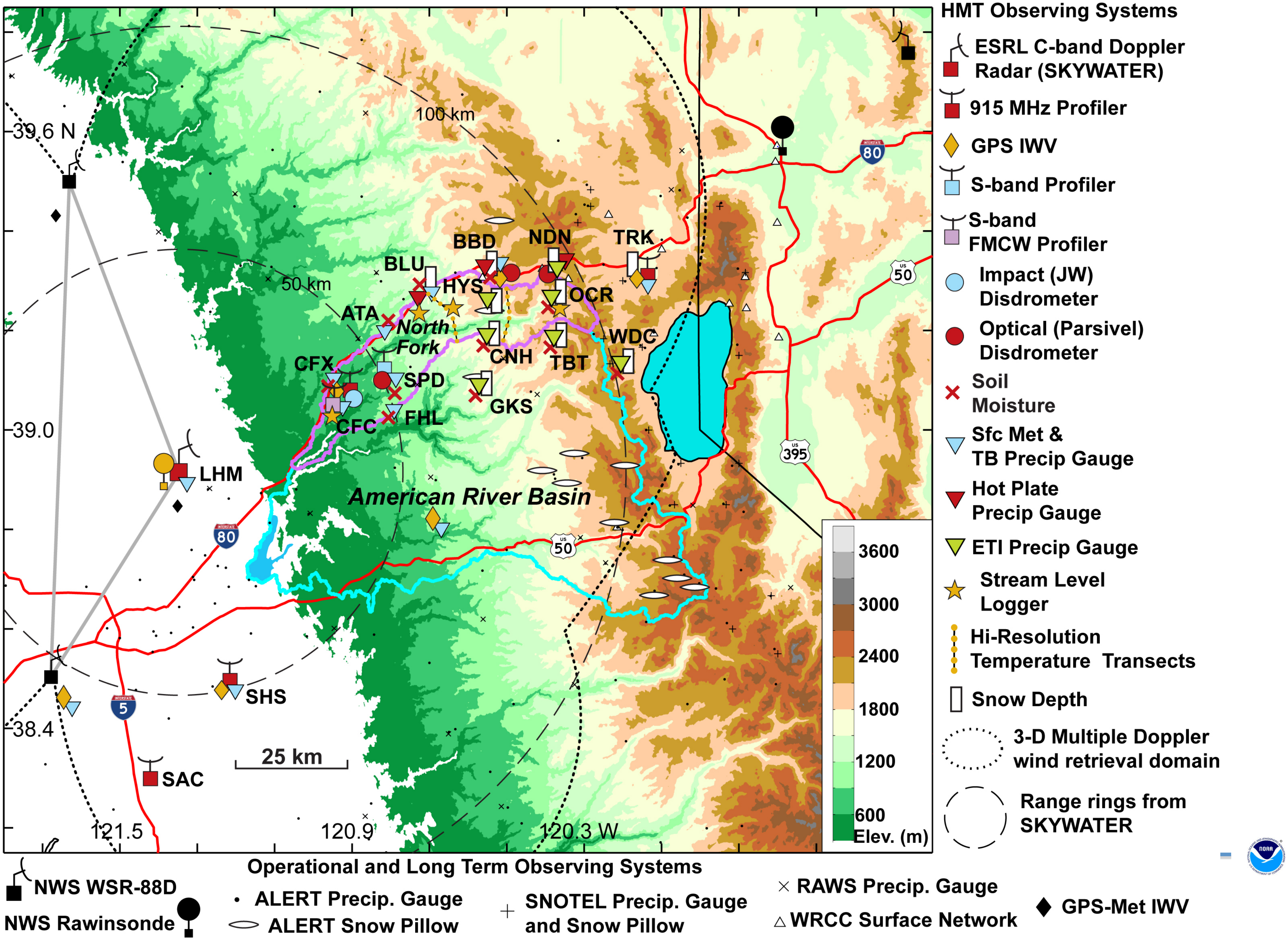


BBY, CCO; CCL:
Since 1998

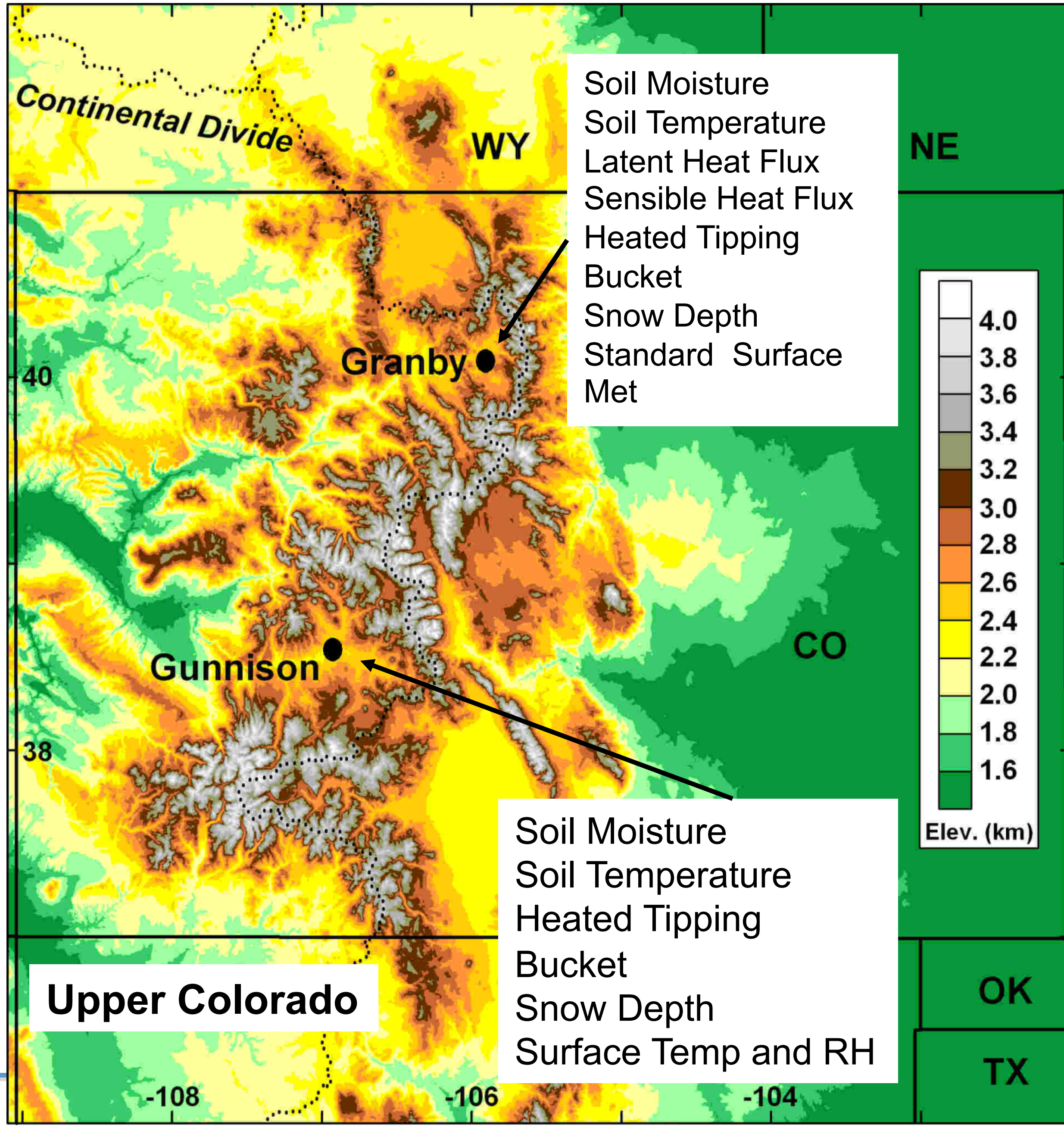
CZD:
Since 2001 (1998)

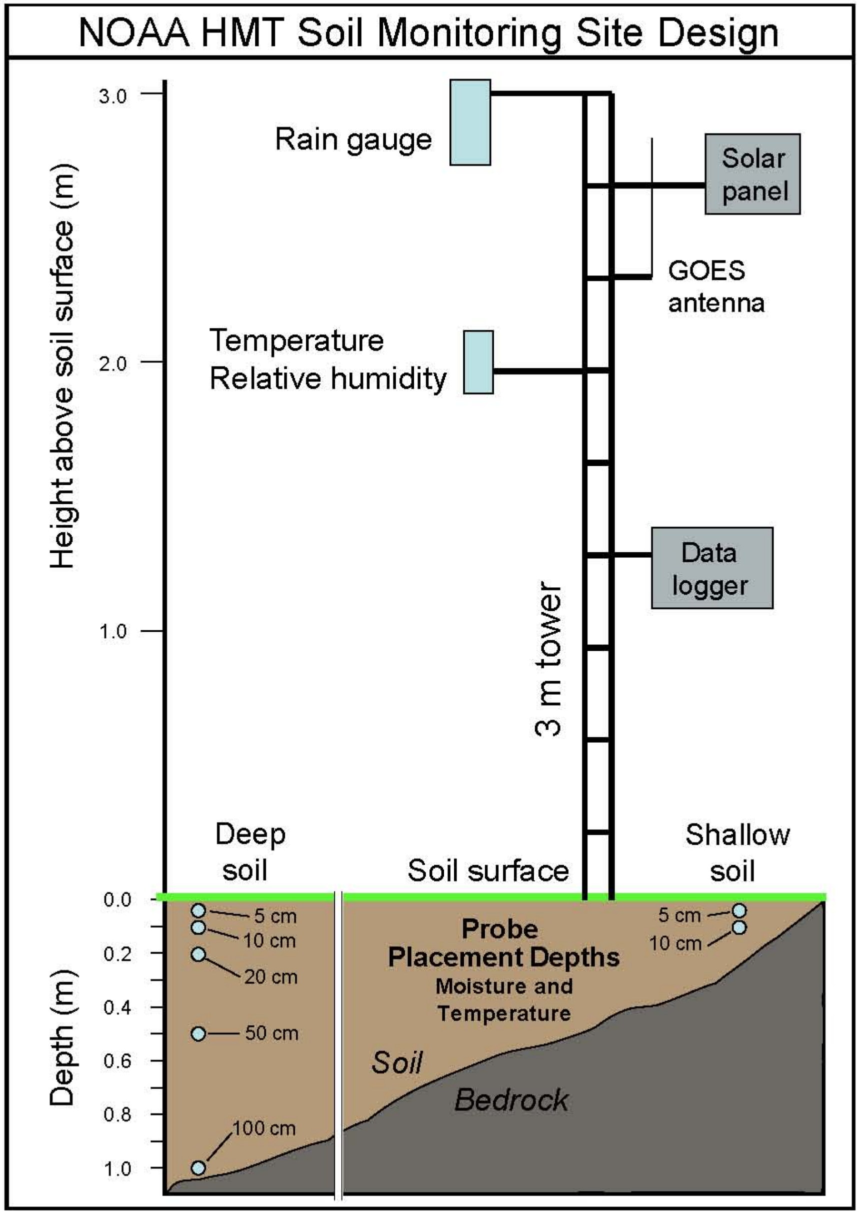
BLU:
Since 2004

HMT-WEST 2010: Basin Scale Domain

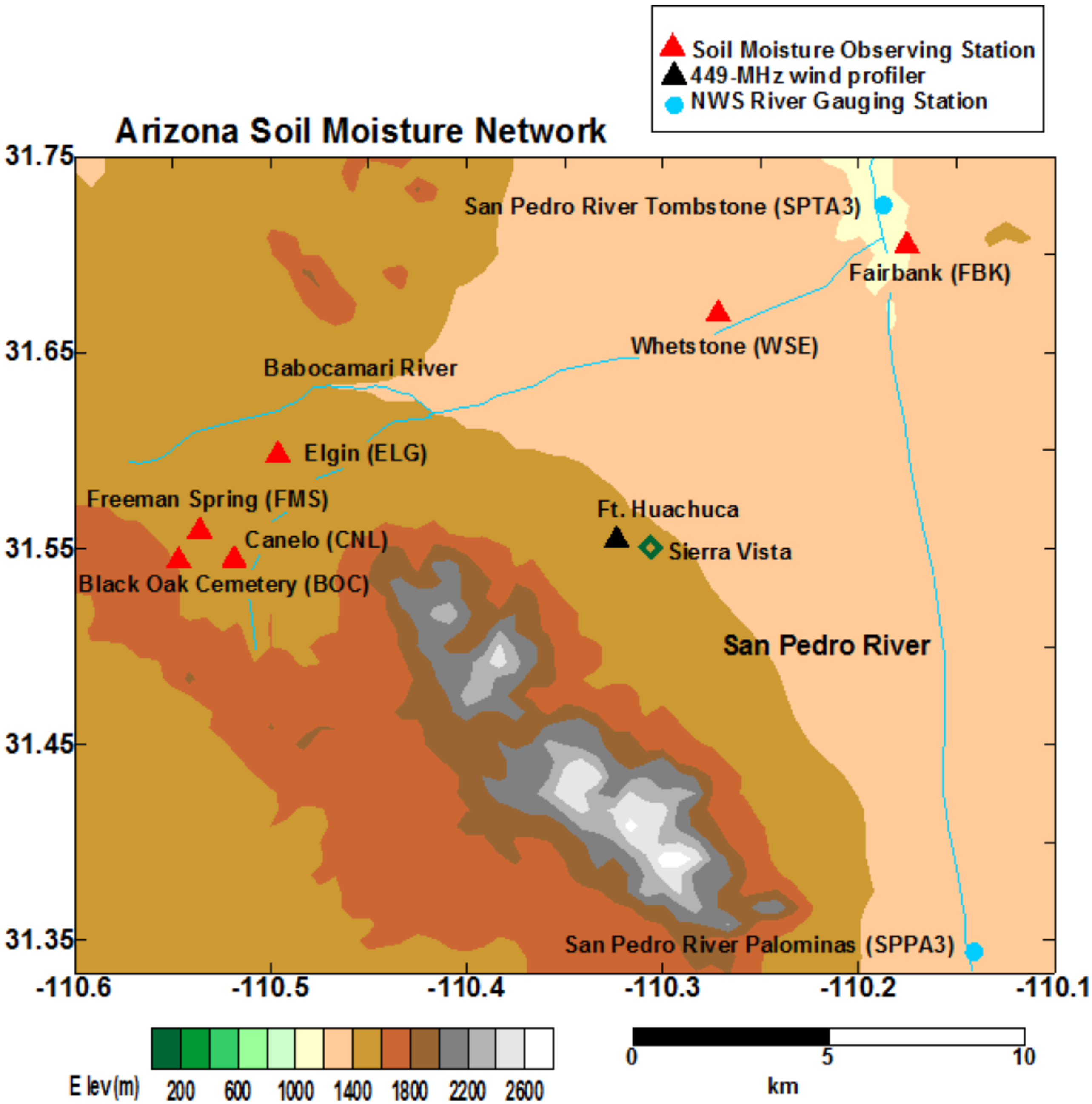


II. Example: Soil Moisture

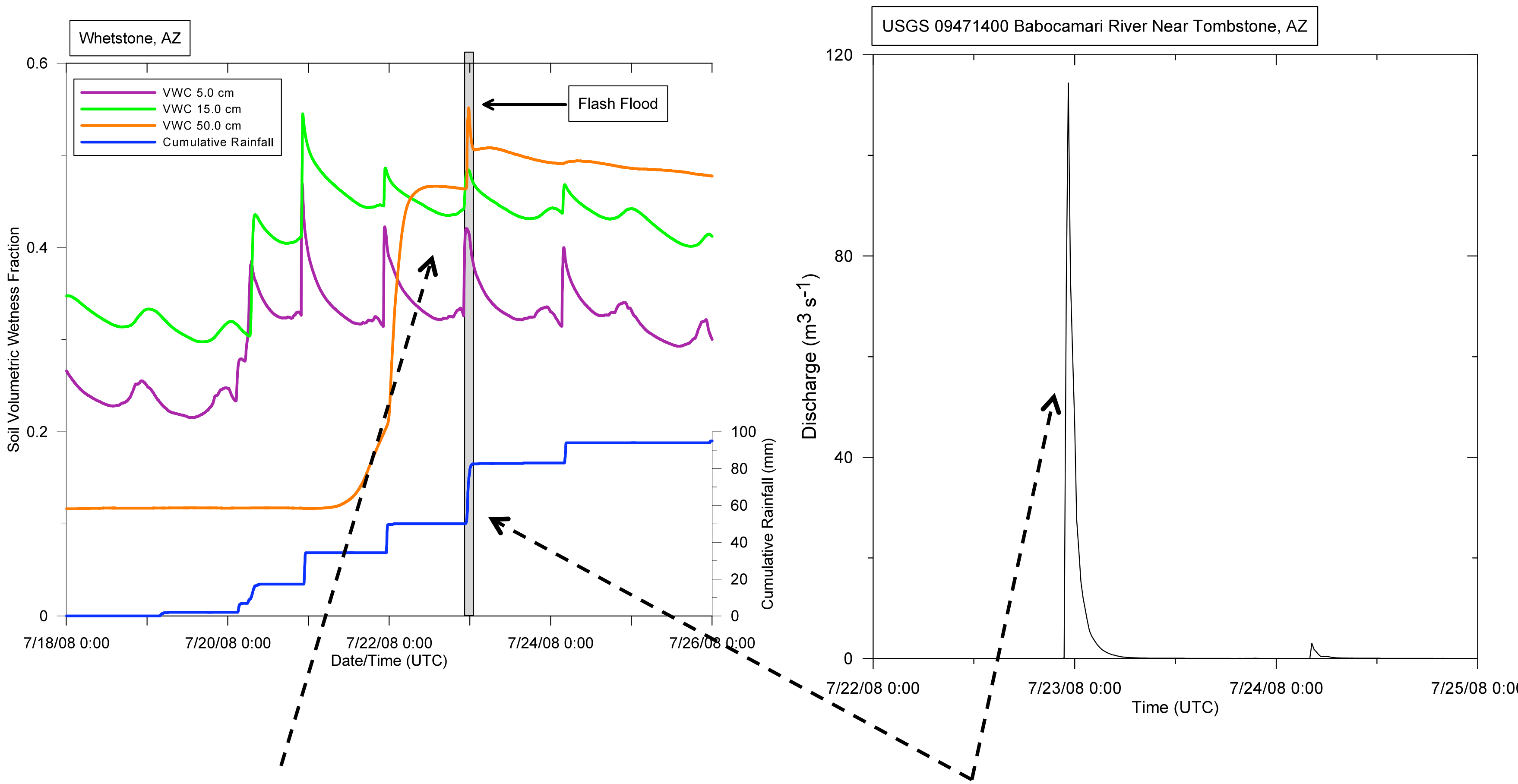

Continental Divide
WY
NE
CO
OK
TX
Granby
Gunnison
40
38
-108
-106
-104
Soil Moisture
Soil Temperature
Latent Heat Flux
Sensible Heat Flux
Heated Tipping
Bucket
Snow Depth
Standard Surface
Met
Soil Moisture
Soil Temperature
Heated Tipping
Bucket
Snow Depth
Surface Temp and RH
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
Elev. (km)
Upper Colorado



Granby, Colorado

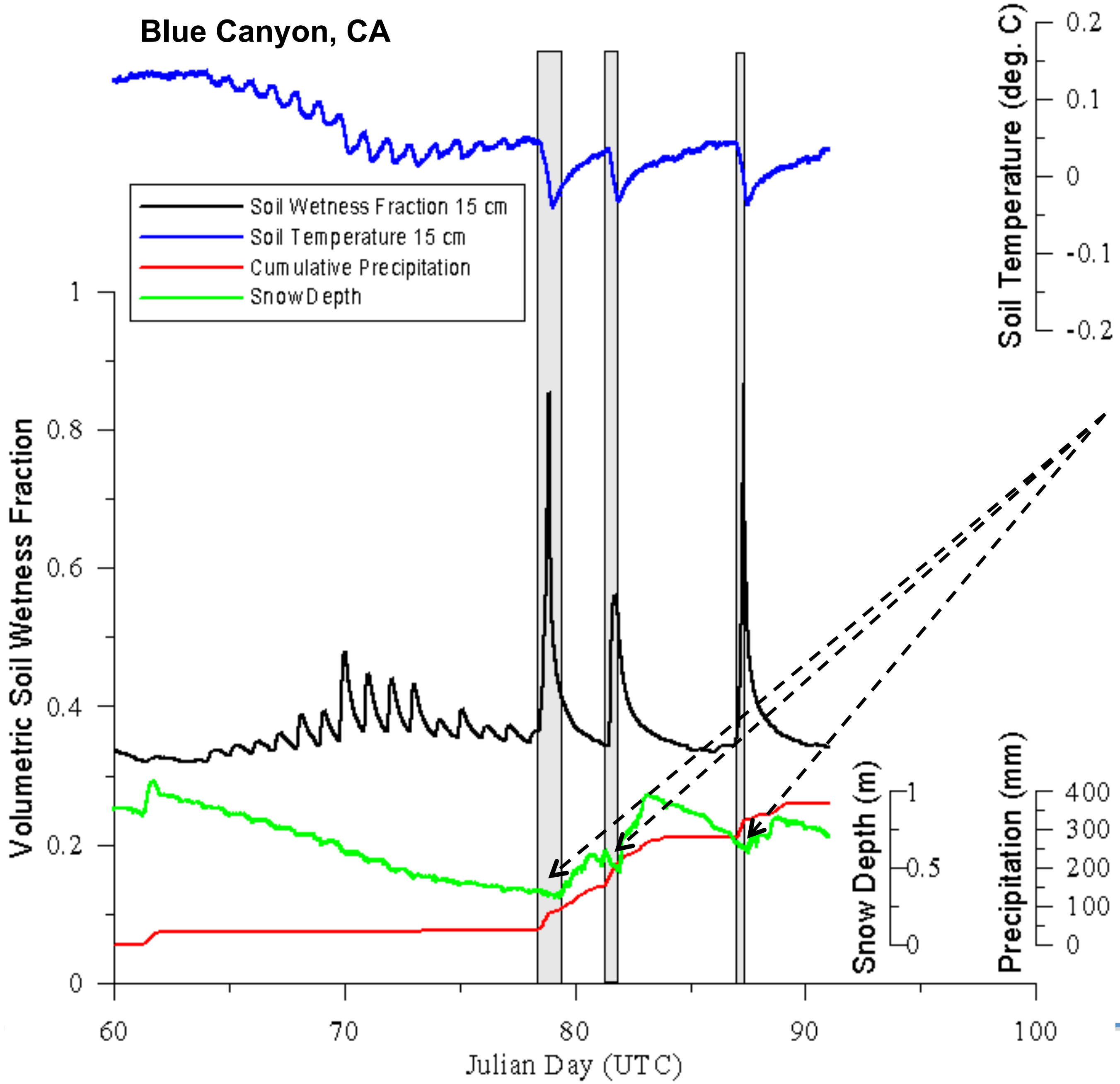


Soil Moisture Observing Station
449-MHz wind profiler
NWS River Gauging Station
Arizona Soil Moisture Network
31.75
31.65
31.55
31.45
31.35
-110.6
-110.5
-110.4
-110.3
-110.2
-110.1
San Pedro River Tombstone (SPTA3)
Fairbank (FBK)
Whetstone (WSE)
Babocamari River
Elgin (ELG)
Freeman Spring (FMS)
Canelo (CNL)
Black Oak Cemetery (BOC)
Ft. Huachuca
Sierra Vista
San Pedro River
San Pedro River Palominas (SPPA3)
Elev(m)
200
600
1000
1400
1800
2200
2600
0
5
10
km



The monsoon rain event occurring on 00 UTC 22July finally brought the soil column to saturation.

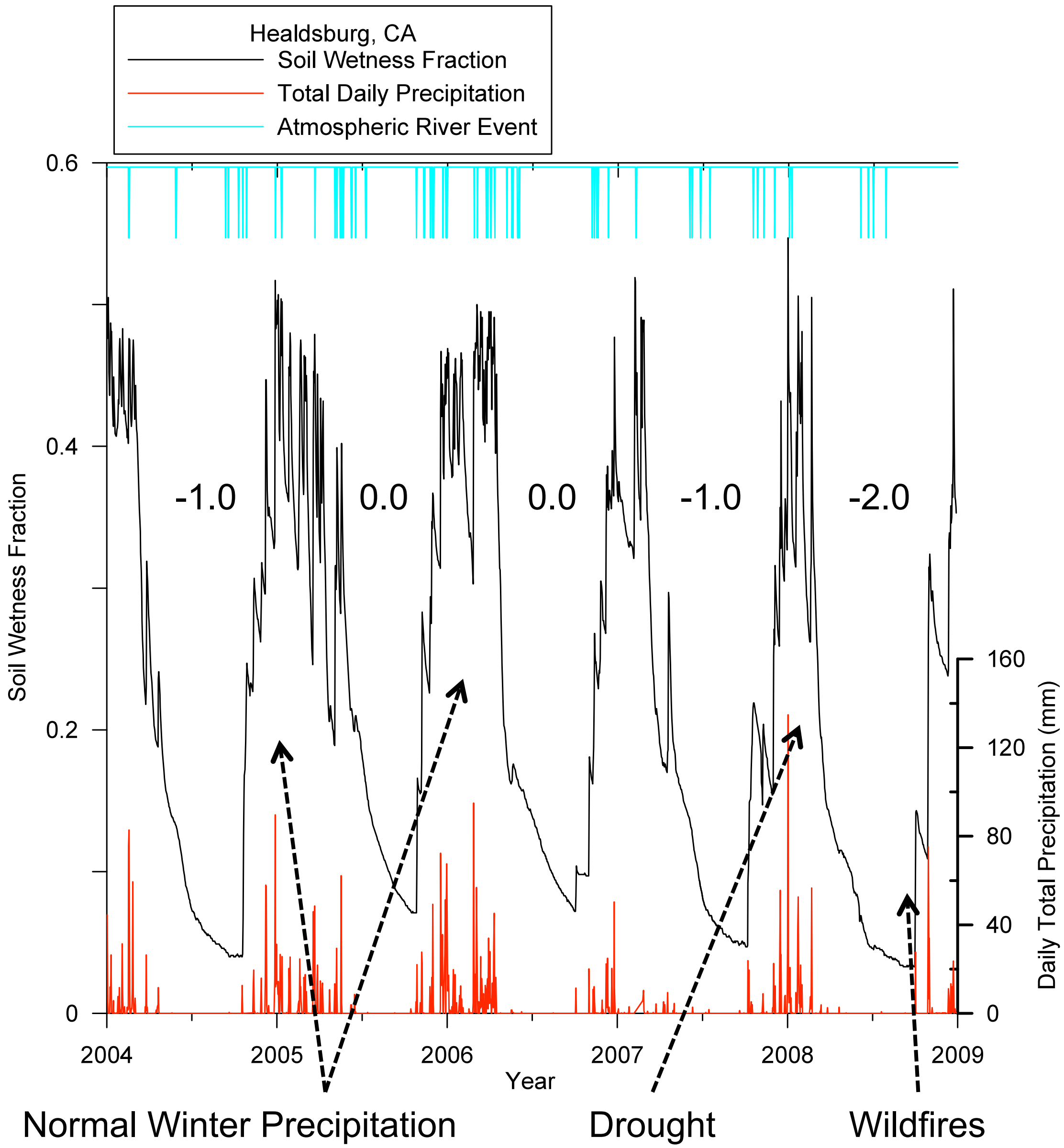
Flooding coincided with a storm that dropped 30 mm of precipitation on top of saturated soil near 00 UTC 23 July.



Snowpack is decreasing at the same time precipitation is being observed suggesting that rain is falling on the snowpack.

Rain is quickly moving through the snowpack and saturating the ground under the snowpack.

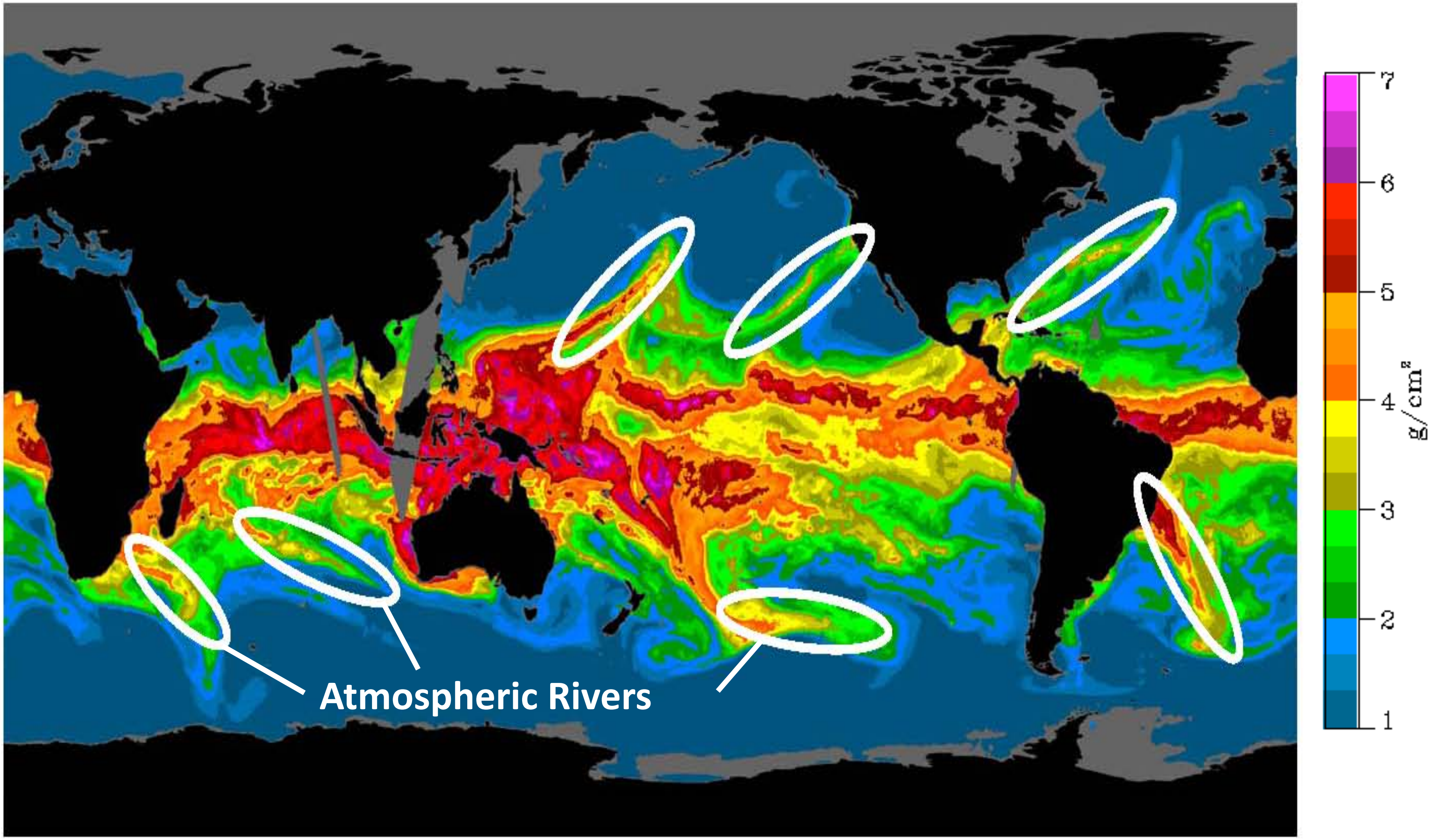
Soil wetness fractions exceeding 0.4 suggest that ponds of water are forming under the snowpack in the saturated soil.



Healdsburg, CA
Soil Wetness Fraction
Total Daily Precipitation
Atmospheric River Event
Soil Wetness Fraction
Daily Total Precipitation (mm)
Year
0
0.2
0.4
0.6
0
40
80
120
160
2004
2005
2006
2007
2008
2009
-1.0
0.0
0.0
-1.0
-2.0
Normal Winter Precipitation
Drought
Wildfires

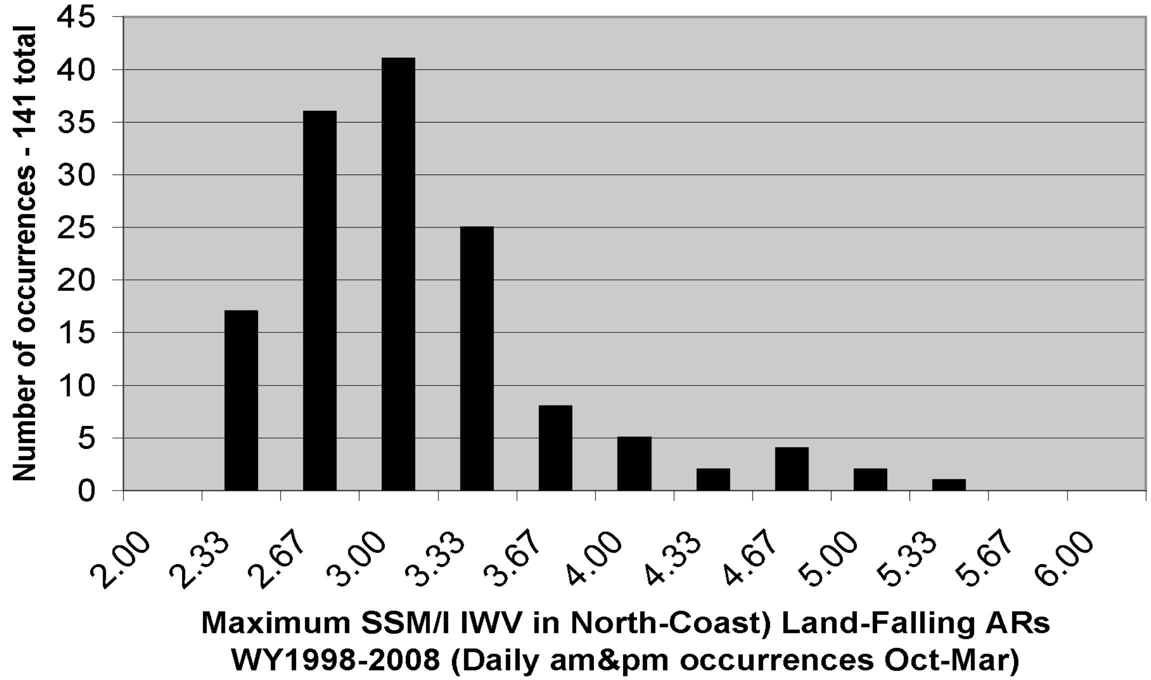
III. Example: Atmospheric Rivers

SSM/I Display of Integrated Water Vapor from February 16, 2004

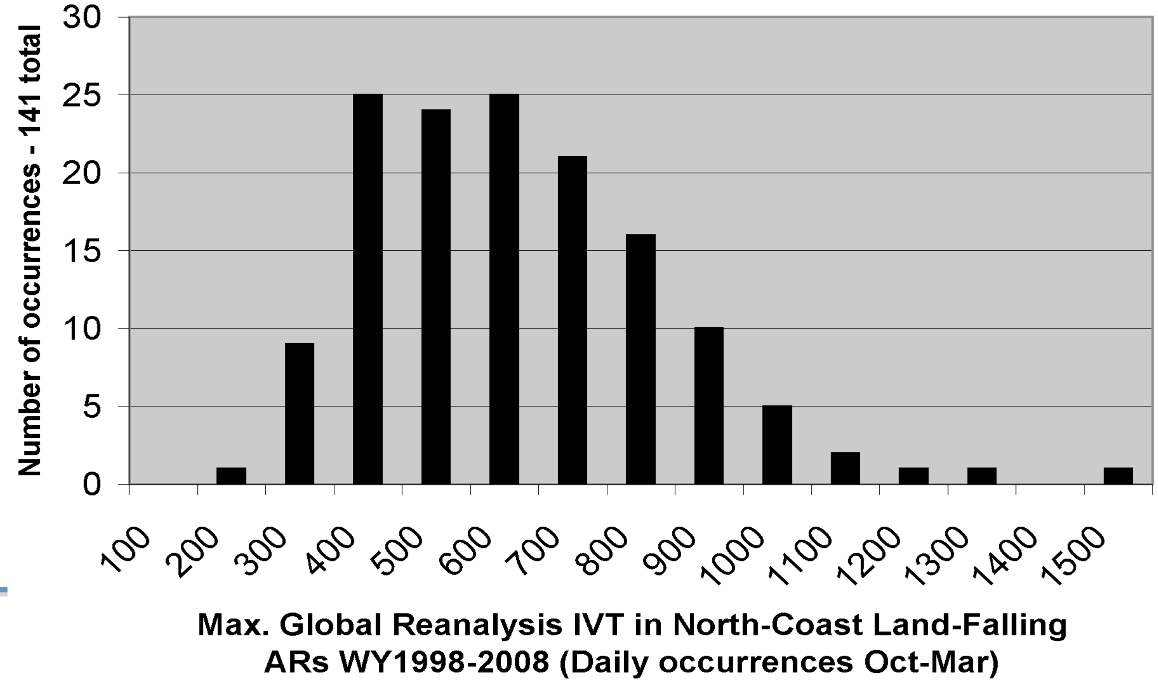


North Coast:
(41.0° - 52.5°N)
Oct-Mar

10 contiguous pixels ($\sim$5000 km^2) of the most moist SSM/I IWV in each AR w/in 1000 km of coast

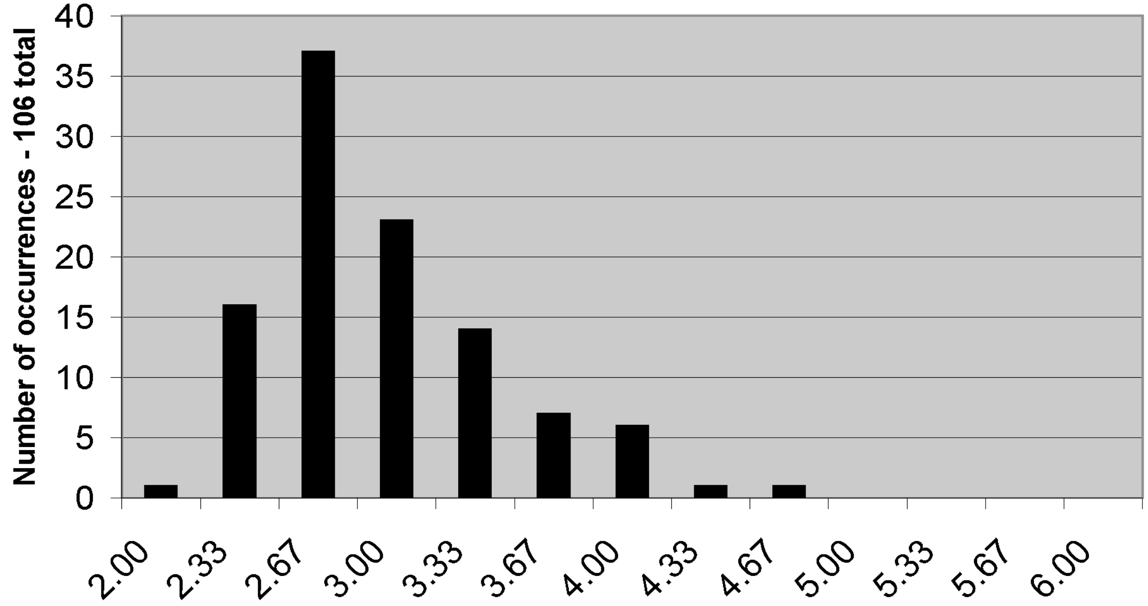


From the above inventory, the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast

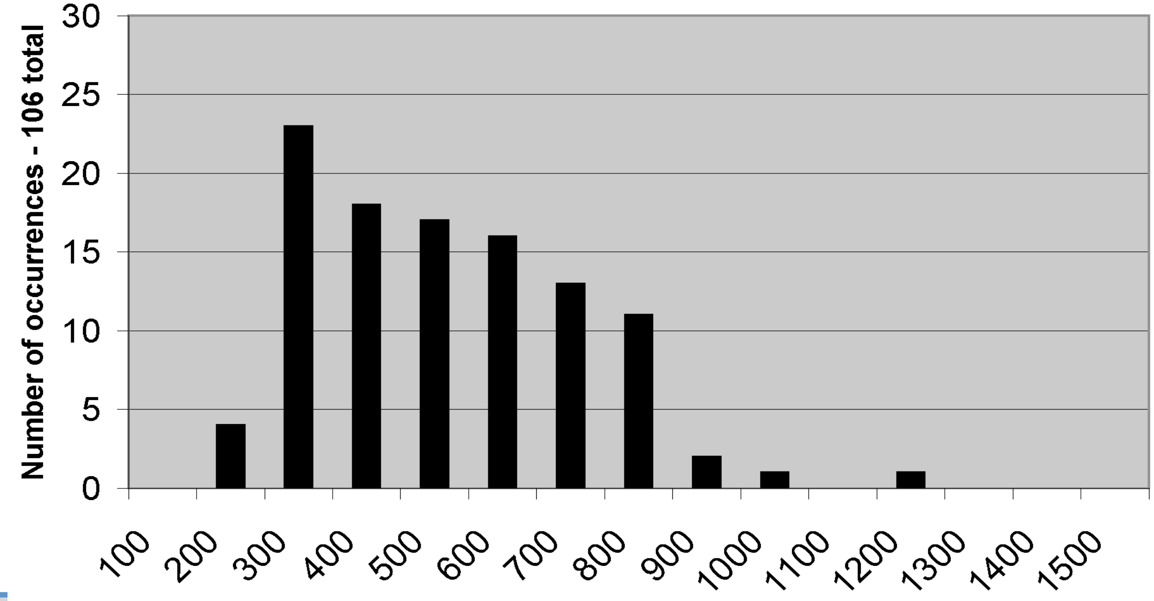


South Coast:
(32.5° - 41.0°N)
Oct-Mar

10 contiguous pixels (~5000 km^2) of the most moist SSM/I IWV in each AR w/in 1000 km of coast

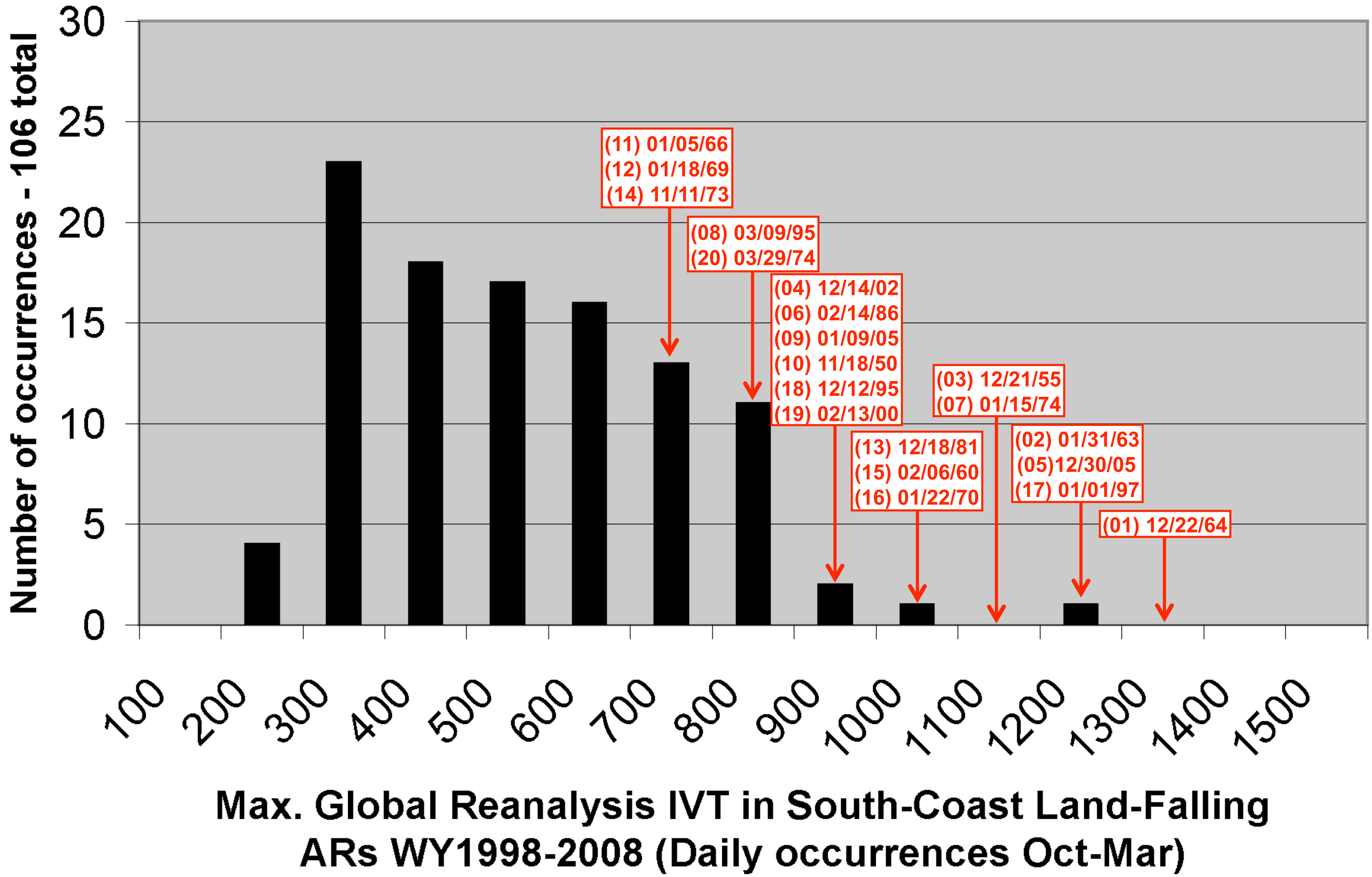


From the above inventory, the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast



CA 20 heaviest 3-day precip. events:

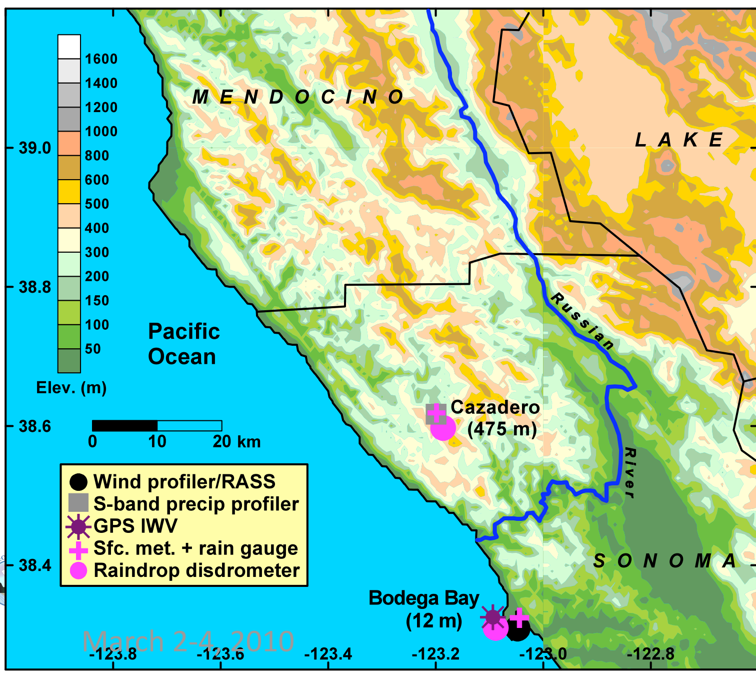
From the above inventory, a histogram of the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast. Dates from the 20 top 3-day precip. events between 1949-2007 (from the CDC 0.25x0.25 deg unified precip. dataset) in the Sierra from Wes Junker are also marked (http://www.hpc.ncep.noaa.gov/research/California_major_rains.htm).

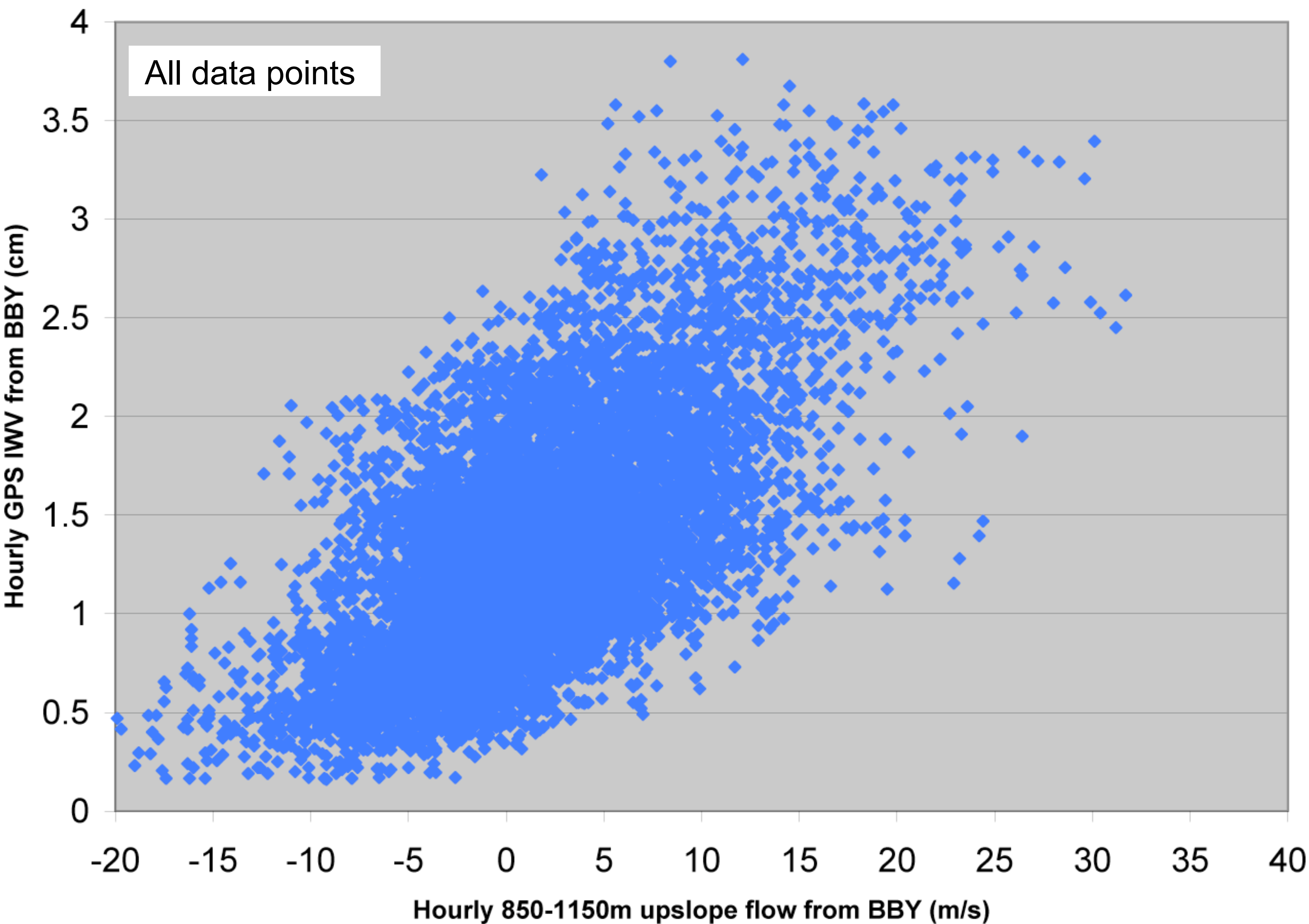


Atmospheric River Observatory (ARO): Russian River Prototype

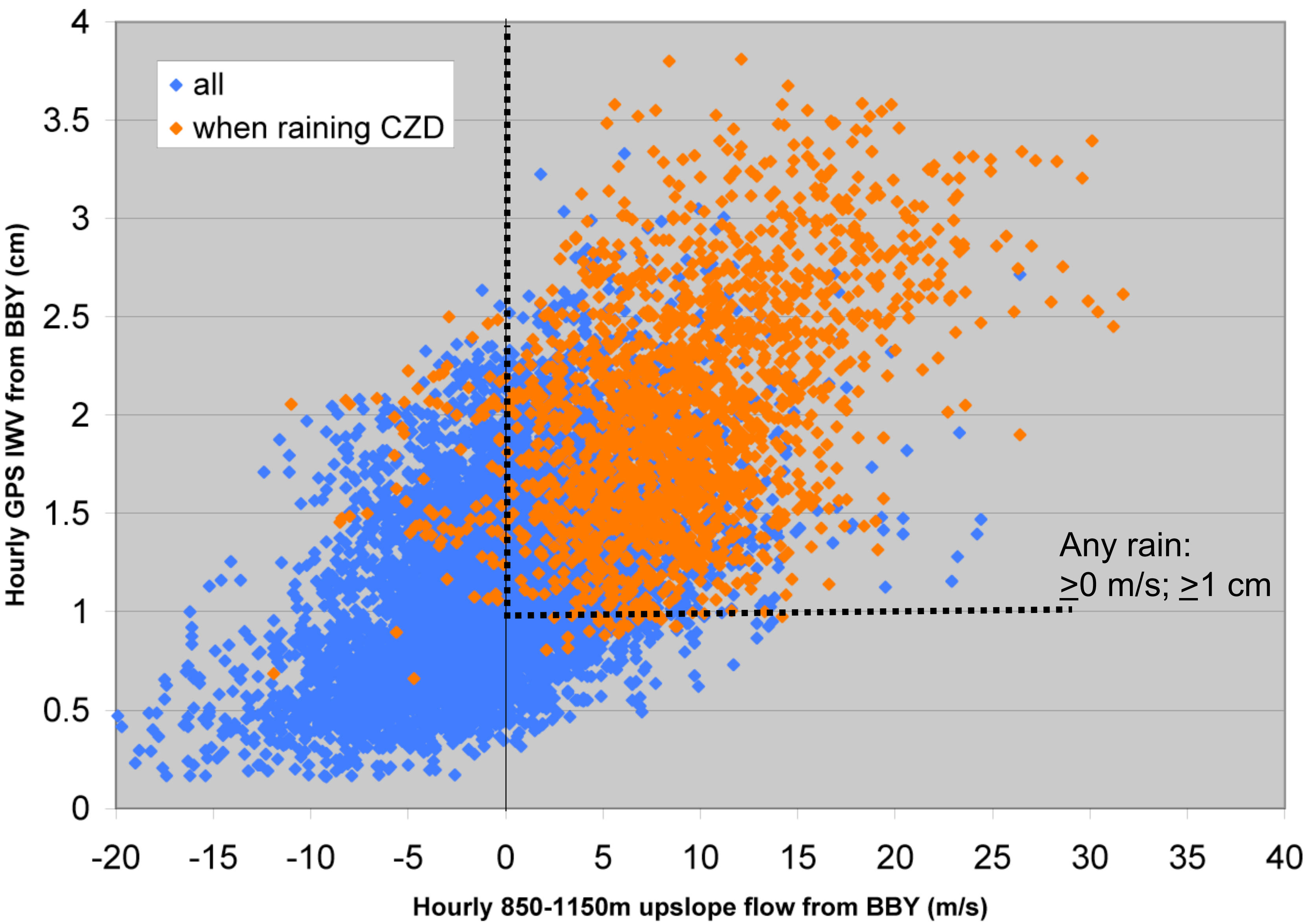
Objectives: monitor key atmospheric river and precipitation characteristics

Observing systems:
1. Wind profiler/RASS
2. S-band radar
3. GPS-IWV
4. Surface met
5. Rain gauges
6. Disdrometer

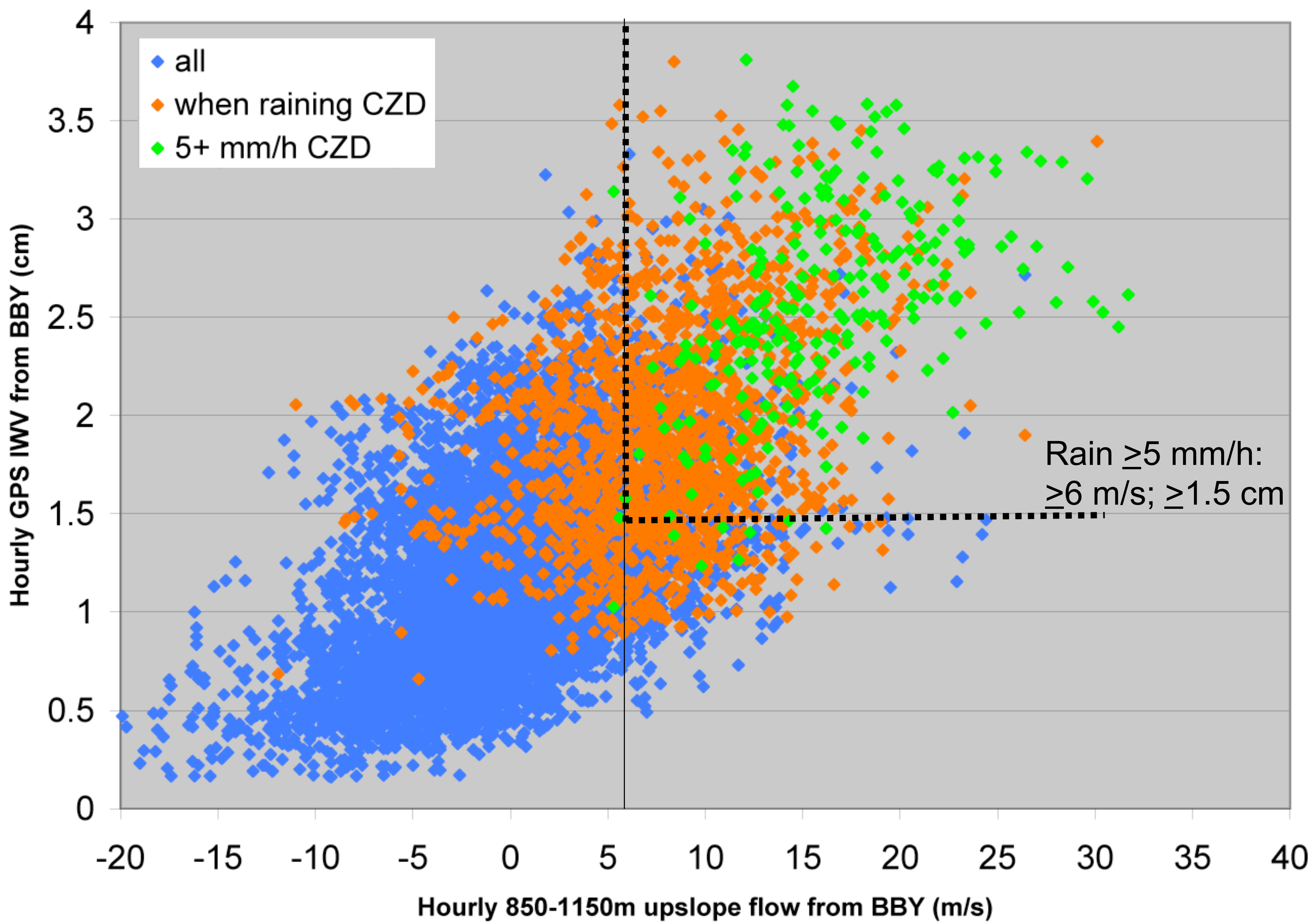


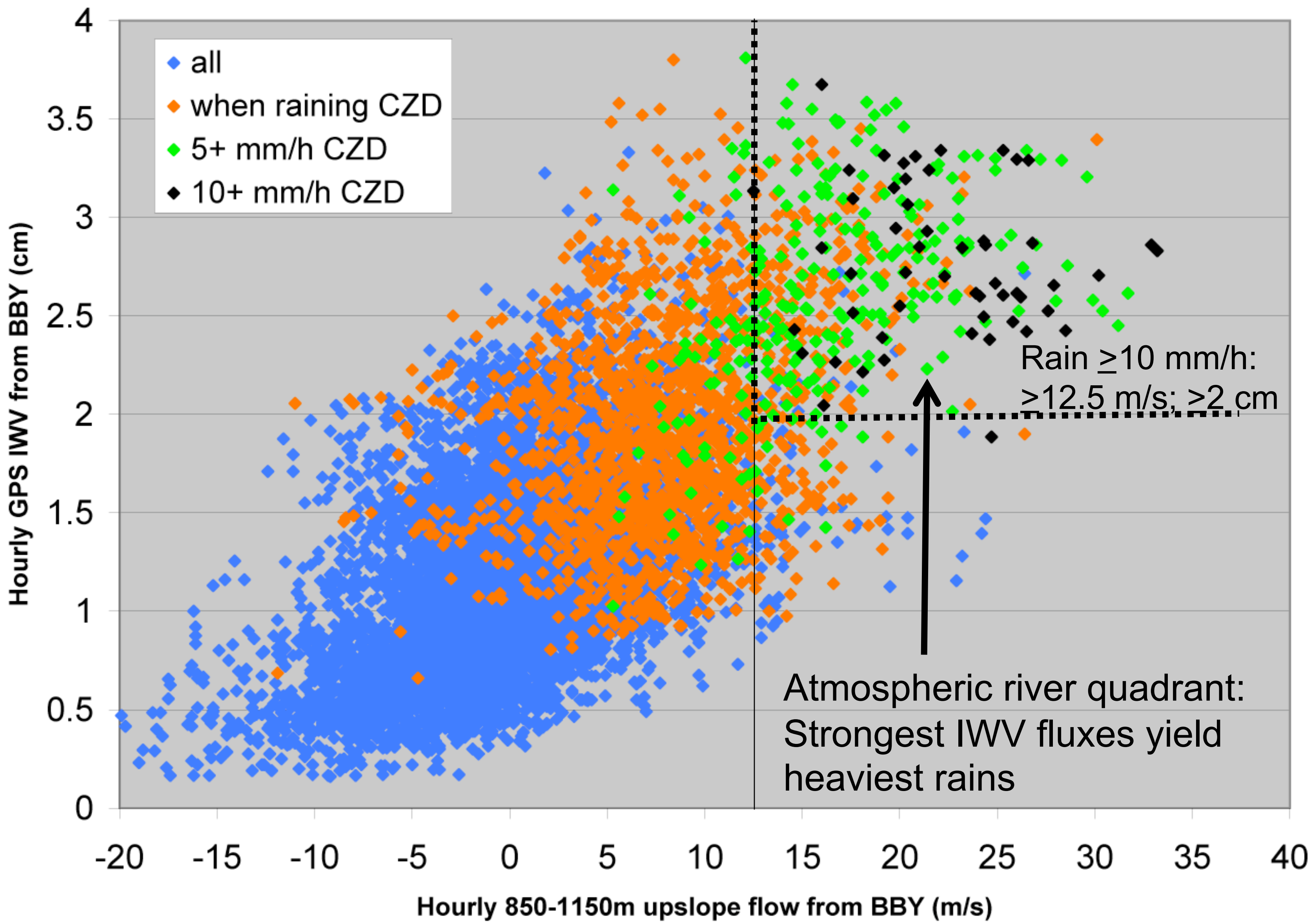


Component of the flow in the orographic controlling layer directed along 230°, i.e., orthogonal to the axis of the coastal mtns



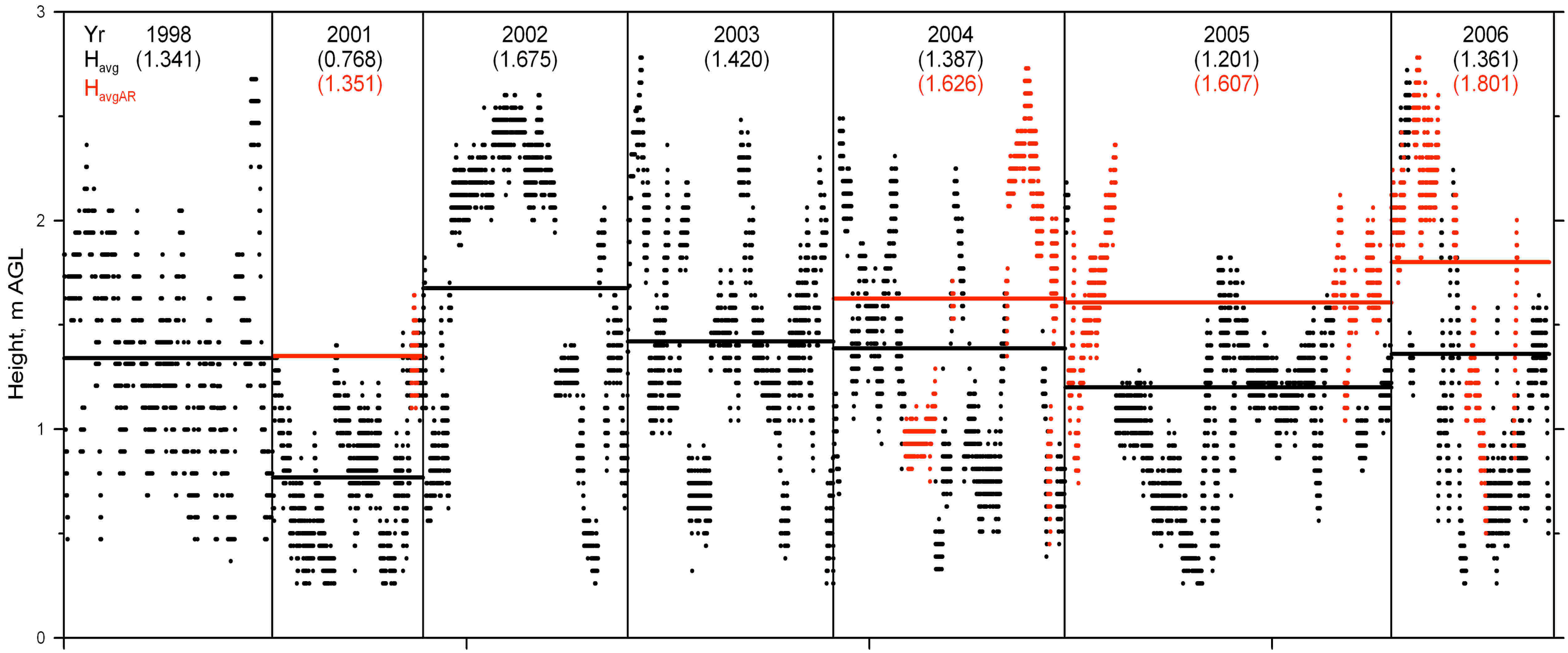
all
when raining CZD
Any rain:
≥0 m/s; ≥1 cm
Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
0
0.5
1
1.5
2
2.5
3
3.5
4
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40


4
3.5
3
2.5
2
1.5
1
0.5
0
all
when raining CZD
5+ mm/h CZD
Rain ≥5 mm/h:
≥6 m/s; ≥1.5 cm
Hourly GPS IWV from BBY (cm)
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
Hourly 850-1150m upslope flow from BBY (m/s)


all
when raining CZD
5+ mm/h CZD
10+ mm/h CZD
Rain ≥10 mm/h:
≥12.5 m/s; ≥2 cm
Atmospheric river quadrant:
Strongest IWV fluxes yield
heaviest rains
Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
0
0.5
1
1.5
2
2.5
3
3.5
4
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40

Snow levels measured by the S-band radar at CZD during the 4 winters averaged 421 m (1380 ft) higher in AR conditions:

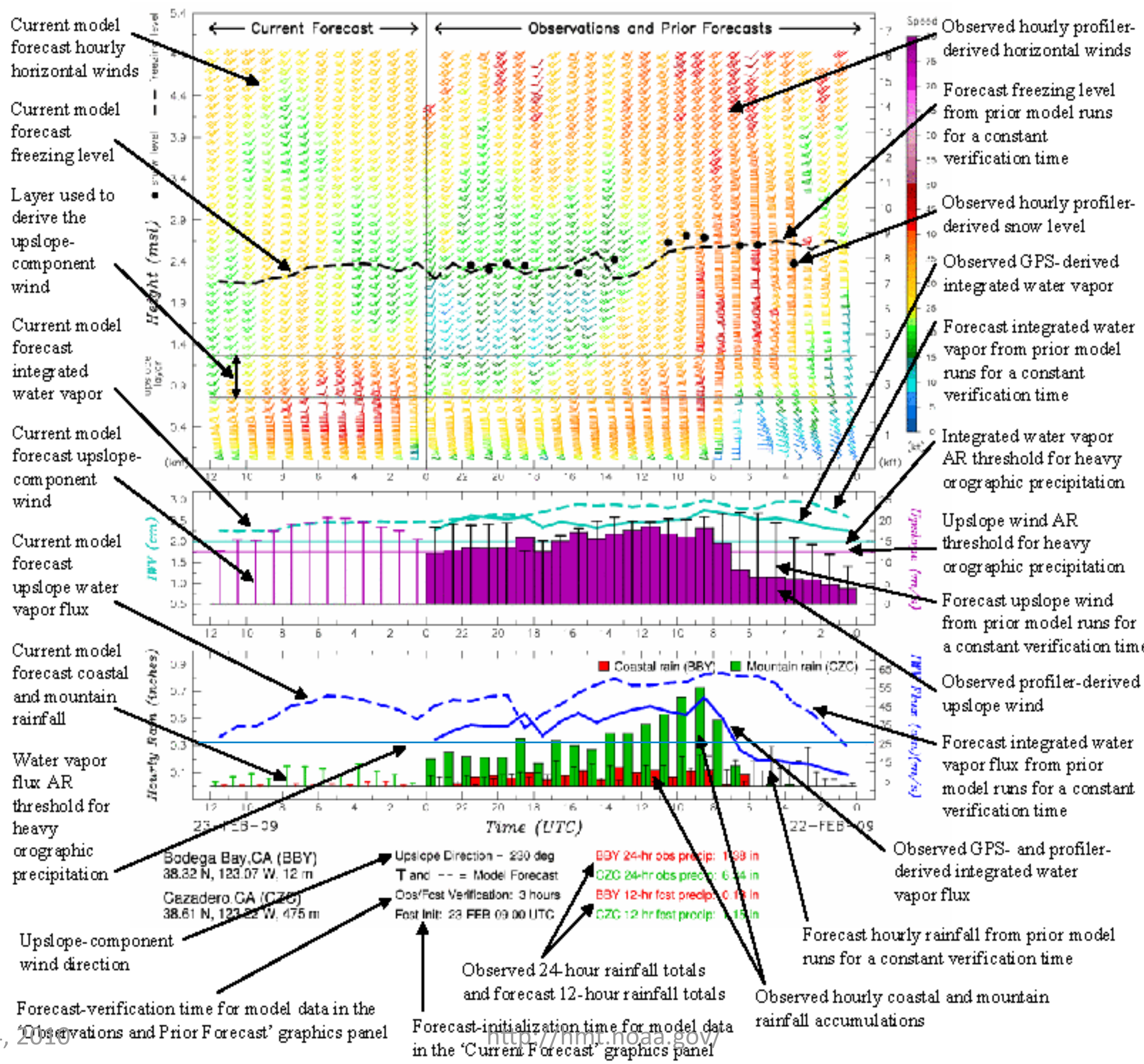
Warm conditions & more rain = increased flooding



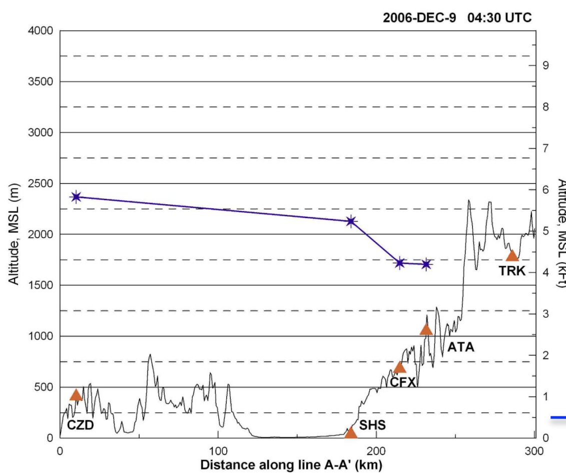

Thank You!
http://hmt.noaa.gov/

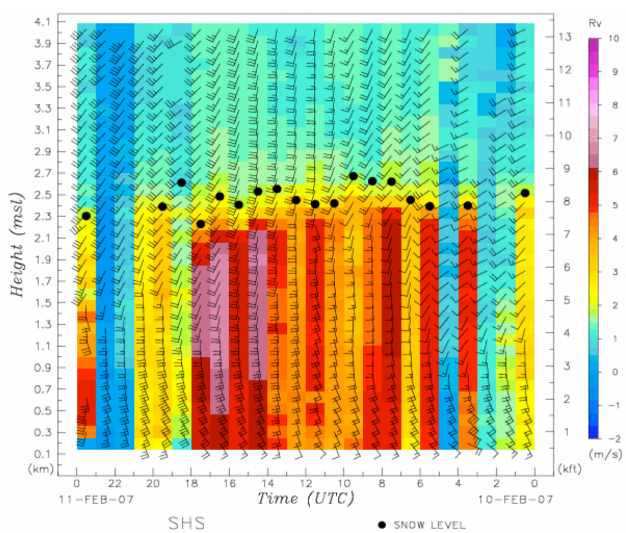
Coastal Atmospheric River (AR) Monitoring and Early Warning System

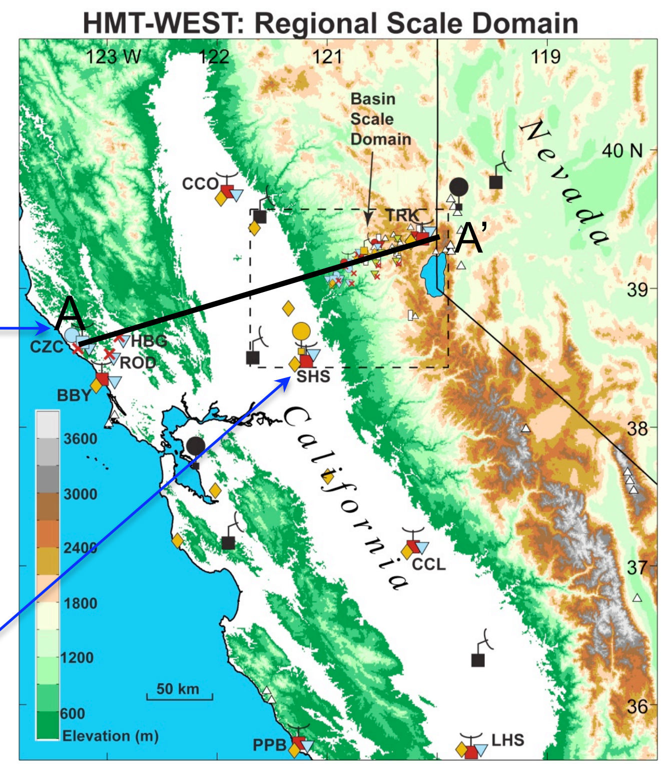
Profiler and precipitation observations provided by the NOAA/ESRL Physical Sciences Division
GPS observations and model forecast provided by the NOAA/ESRL Global Systems Division



Snow Level Varies Significantly in Space & Time







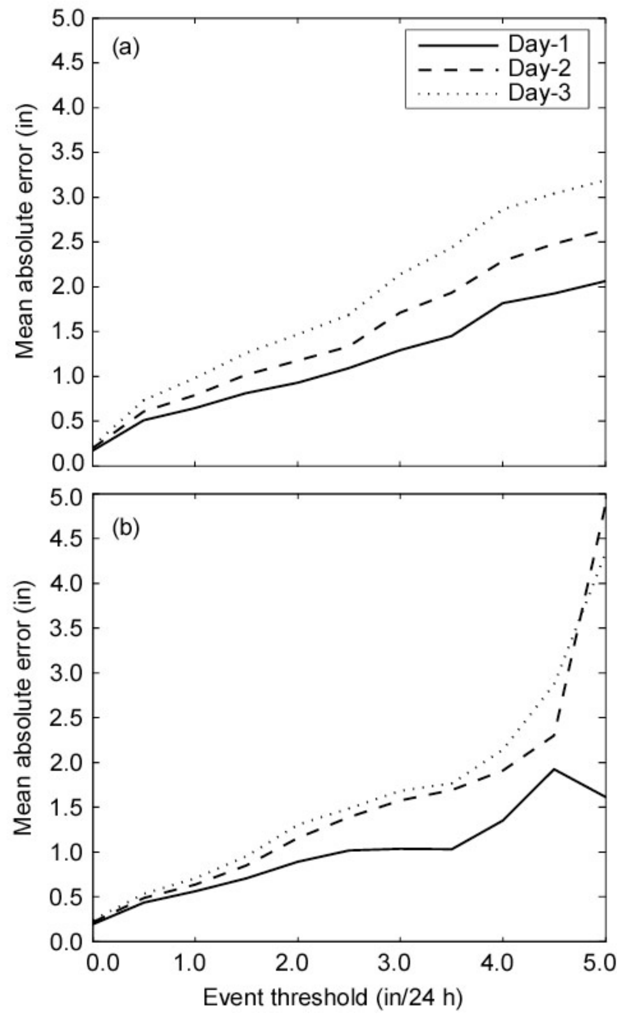


Figure 6. Mean absolute error for 24-h precipitation thresholds (in inches) by forecast lead time (Day-1, Day-2, and Day-3) for the (a) CNRFC and (b) NWRFC.

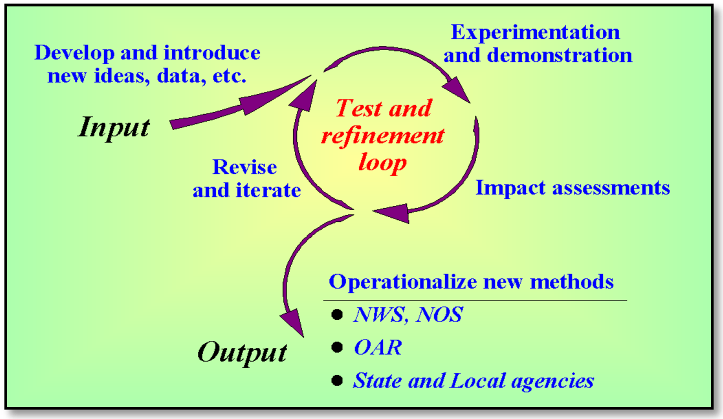
Partnerships on Research, Demonstration, Evaluation & Impact Assessment

<u>NOAA Research:</u>
- ESRL – PSD
- ESRL – GSD
- NSSL

<u>National Weather Service:</u>
- OHD
- NCEP/HPC
- OCWWS/NOHRSC
- Western Region HQ
- Eastern Region HQ
- Southern Region HQ
- River Forecast Centers: California-Nevada; Colorado Basin; Southeast
- Weather Forecast Offices: Eureka, Monterey, Sacramento, Reno, Seattle, Raleigh-Durham

<u>NESDIS</u>
- STAR

- Federal Agencies
  - NASA; USGS; US-ACE
- State Agencies
  - CA-DWR; NC-RENCI
- Local Agencies
  - SAFCA
- Academic
  - CU; CSU; UW; UCSD/Scripps; NCAR



		HMT Major Activity Area					
Phenomena	Paper	QPE	QPF	SI	HA	V/ DST	DF
Atmospheric Rivers (8)	Bao'06		✓		✓	✓	
	Junker'09		✓			✓	
	Neiman'08a	✓	✓	✓	✓	✓	
	Neiman'08b	✓	✓	✓	✓	✓	
	Ralph'06		✓		✓	✓	
	Ralph'05a		✓			✓	
	Ralph'04		✓		✓	✓	
	Wick'08		✓		✓	✓	
Warm Rain Processes (4)	Kingsmill'06	✓	✓			✓	
	Martner'08	✓	✓		✓	✓	
	Neiman'05	✓	✓		✓	✓	
	White'03	✓	✓		✓	✓	
Orographic Effects (7)	Neiman'10	✓				✓	
	Neiman'06		✓				
	Neiman'04		✓			✓	
	Neiman'02		✓		✓	✓	
	Nuss'01		✓			✓	
	Smith'10		✓			✓	
	Ralph'03	✓	✓		✓	✓	
Observing Systems (15)	Dabberdt'05	✓	✓		✓	✓	
	Gourley'09	✓			✓	✓	
	Lundquist'09	✓		✓	✓		
	Lundquist'08a			✓	✓		
	Lundquist'08b			✓	✓		
	Martner'07	✓					
	Matrosov'10	✓		✓		✓	
	Matrosov'09	✓		✓			
	Matrosov'08	✓		✓		✓	
	Matrosov'07	✓		✓			
	Matrosov'05	✓				✓	
	Matrosov'04	✓		✓			
	Neiman'09		✓	✓	✓	✓	
	White'02			✓	✓	✓	
	White'00	✓		✓			
Precipitation Forecasting (6)	Jankov'09		✓			✓	
	Jankov'07		✓				
	Junker'08		✓			✓	
	Morss'07	✓	✓		✓	✓	
	Ralph'05b	✓	✓	✓	✓	✓	
	Yuan'08		✓				
Physical Processes (7)	Andrews'04		✓		✓		
	Coplen'08	✓					
	Jorgensen'03	✓	✓		✓		
	Persson'05		✓		✓	✓	
	Restrepo'08	✓				✓	✓
	Richiardone'09					✓	
	Wilczak'07					✓	

47 peer reviewed papers since 2000

Appearing in Journals:
- Monthly Weather Review
- J. Hydrometeorology
- J. Atmos. & Oceanic Tech.
- Bull. Amer. Meteor. Soc.
- Geophys. Res. Let.
- *Proc. Institution of Civil Engineers* – Water Resource Res.
- Weather & Forecasting
- IEEE Trans. on Geosci. & Rem. Sens.
- J. Appl. Meteor. & Climatology
- J. Climate
- Nonlin. Proc. in Geophys.
- Prog. in Oceanography
- Water Management

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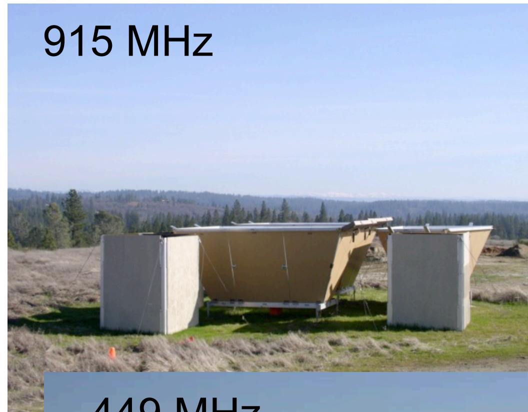
- NOAA ESRL PSD
- NOAA ESRL GSD
- NOAA NSSL
- NOAA NWS NCEP
- NCAR/Societal Impacts Program
- USGS
- CIRES/University of Colorado
- CIRA/Colorado State University
- Naval Postgraduate School
- University of Washington
- Universit`a di Torino, Torino, Italy
- Contributing authors represent an additional 10 or more institutions

HMT Observing Systems

Scanning Radars

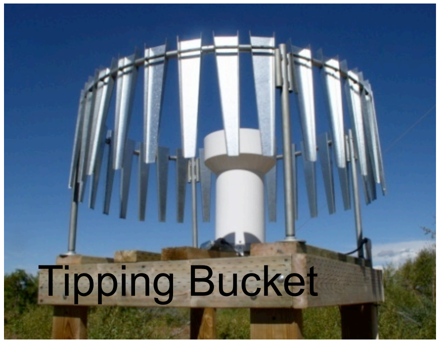
Profiling Radars



GPS IWV & Sounding Systems

HMT Observing Systems

Precipitation Gauges



Precipitation Disdrometers

Surface Meteorology & Snow Depth

Soil Moisture

Streamlevel

Quantitative Precipitation Forecasting Timescales in HMT

Subseasonal Forecasting (Weickman & Berry, 2009):
- global synoptic dynamic model (GSDM)

Reforecasting (Hamill & Whitaker, 2006):
- statistical post-processing
- downscaling
- analogues for various fields

Ensemble Forecasting (Jankov et. al., 2009):
- high resolution
- ensembles of deterministic forecasts

QPF: 14 days +

QPF: 5-14 days

QPF: 3-5 days

QPF: 0-3 days

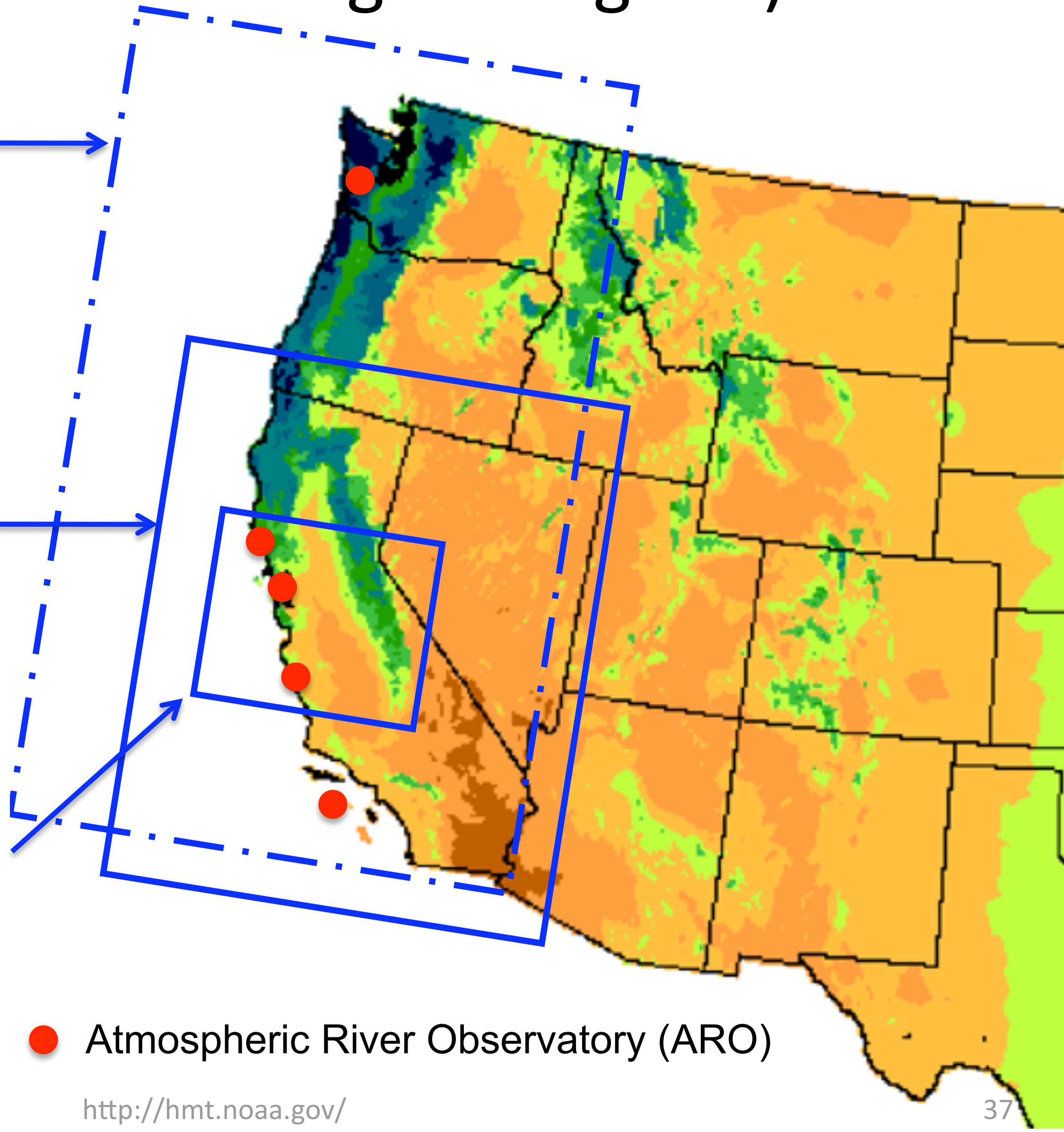
NowCast: QPE->24 hrs.(?)

Downscaling (e.g. PRISM)

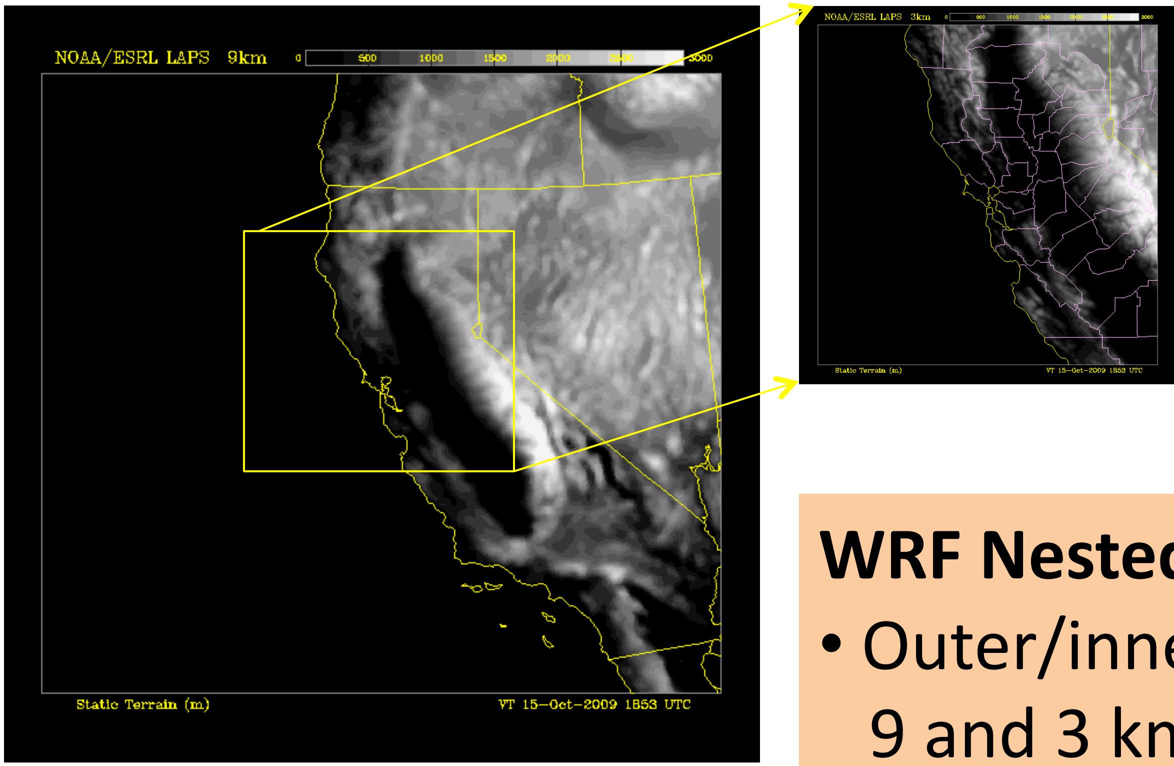
Observations: Verification & Assimilation

HMT-West 2010: WRF Ensemble Modeling Domains (Tentative; Fine Tuning in Progress)

- Single Deterministic Run for the *Atmospheric River Monitoring and Early Warning System*
  - 12 hour forecast; 1 hour updates
  - 10 km horizontal resolution
- 8-Member Ensemble Run for Probablistic Forecasts
  - 120 hour forecast; 6 hour updates
  - 9 km horizontal resolution
- 8-Member Super High-Resolution Ensemble Run for Probablistic Forecasts (nested)
  - 12 hour forecast; 6 hour updates
  - 3 km horizontal resolution



HMT-West EXPERIMENT DESIGN for 2009-2010



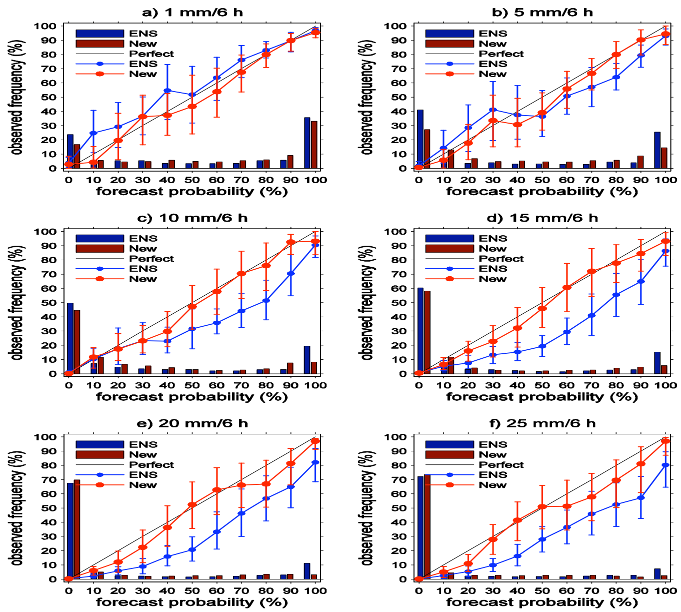
WRF Nested domain:

- Outer/inner nest grid spacing 9 and 3 km, respectively,
- 6-h cycles,
- Outer nest: 120 fcst hours,
- Inner nest: 12-h fcst hours.

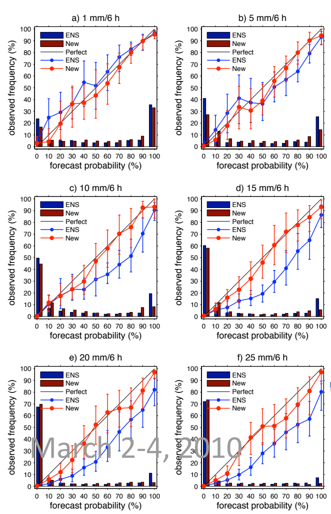
HMT-West ENSEMBLE DESIGN for 2009-2010

- 3 WRF-ARW RUNS AND 1 WRF-NMM RUN
    - WRF-ARW runs: Ferrier, Schultz, Thompson microphysics
    - WRF-NMM run: Ferrier microphysics
- 8 GFS ensemble members will provide LBCs for the mixed-model, mixed-physics ensemble
- One additional member will use WRF-ARW with Thompson microphysics and GFS deterministic run will provide LBCs,
- Time lagging optional
- The ensemble mean and probabilistic products will be displayed on ALPS

Calibration of PQPF (statistical post-processing)

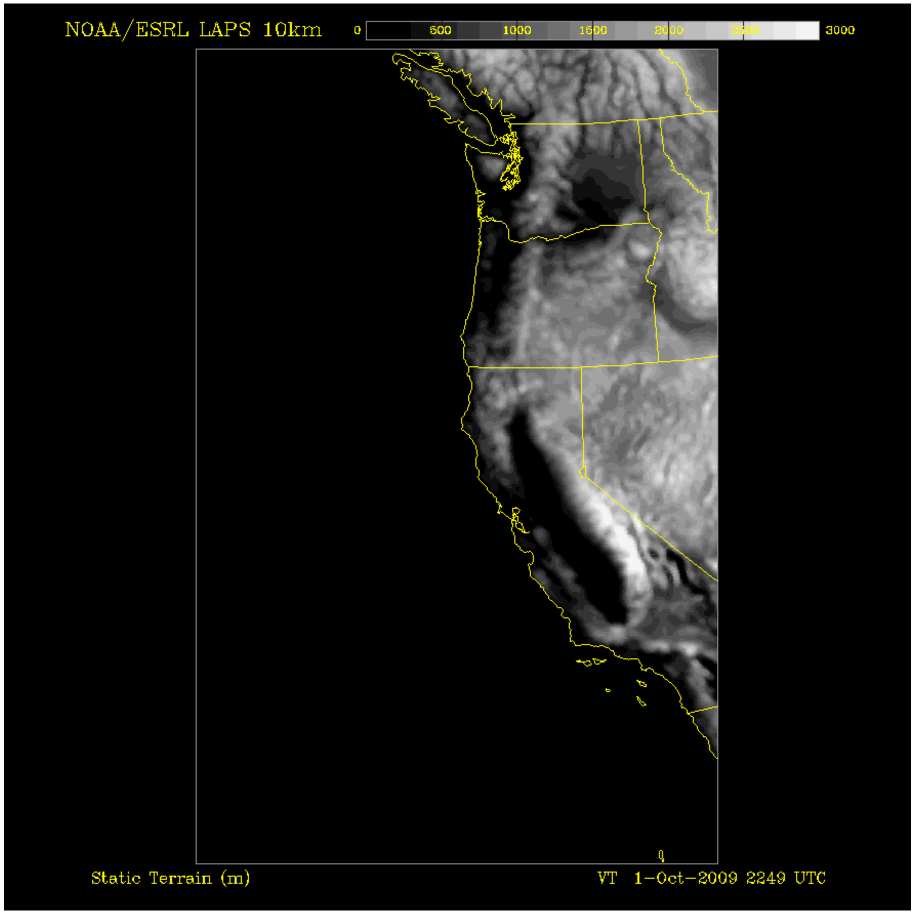


An example of probabilistic QPF (PQPF) calibration by using linear regression. The reliability notably improved after the calibration. Several IOPs were used for training purpose.



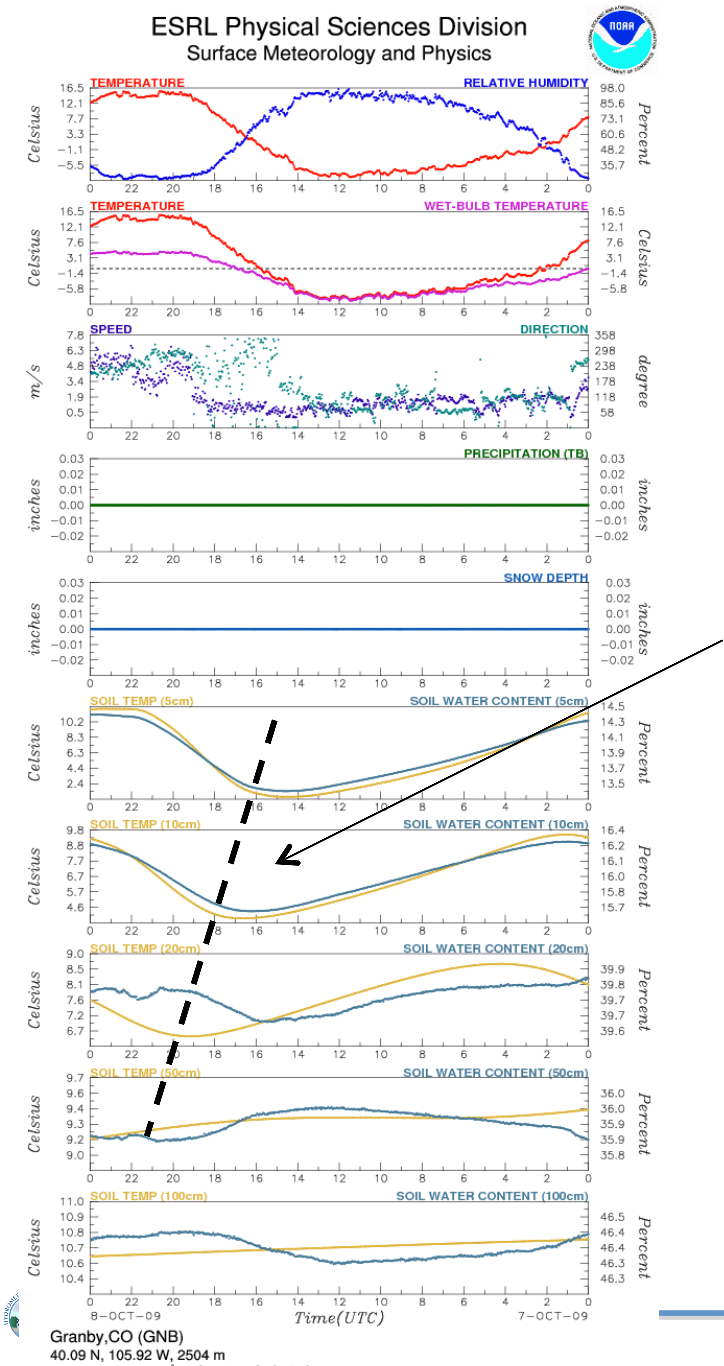
SEPARATE HIGH-RESOLUTION MODEL RUN FOR PSD's MOISTURE-FLUX FORECASTING TOOL for 2009-2010

- Domain extended further north and south compared to the ensemble domain
- 10 km horizontal grid spacing
- Hourly update
- 12-hr forecast
- LAPS initial conditions
- NAM LBCs
- HRRR profiles will be extracted



The PSD observations made in the Upper Colorado River Basin will support research and operations by providing information about soil moisture, soil temperature, snow depth, latent heat flux, sensible heat flux, net radiative flux, ground heat flux, wind speed, wind direction, surface pressure, temperature and relative humidity.

- Granby and Gunnison, CO selected for instrumentation
- Granby selected for snow sublimation studies
- Granby soil moisture probes along with standard surface meteorological instrumentation were installed and operational on10/2/09
- Granby eddy flux tower installation planned for May 2010.
- Gunnison soil station installation planned for June 2010
- CBRFC would like to validate NWS hydrological models using observations made in the Gunnison River Basin



Granby operational as of October 2, 2009

- Well defined diurnal heat wave in the soil
- Amplitude of the wave decreases with depth
- Soil moisture increases with depth

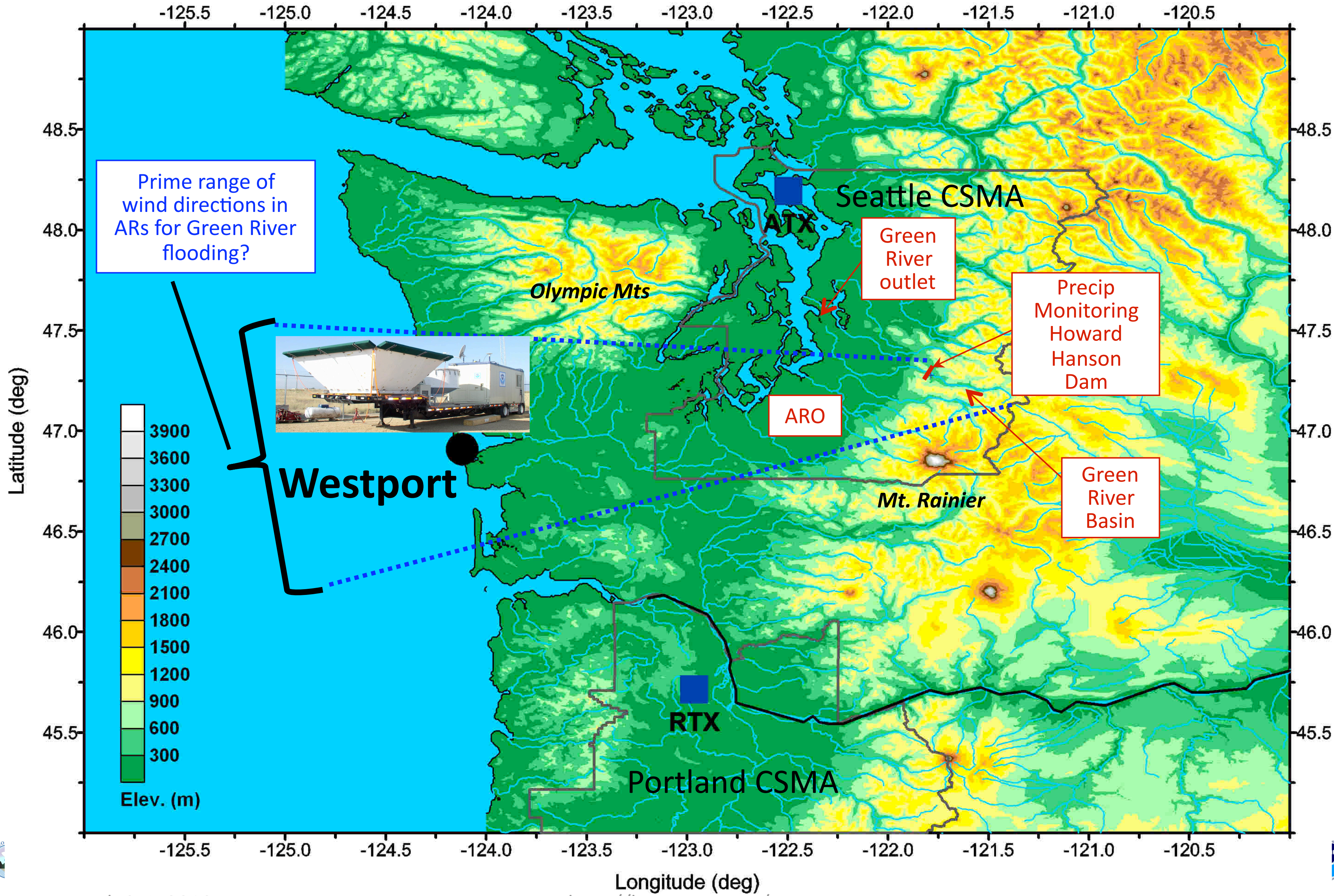
Data: http://www.esrl.noaa.gov/psd/data/obs

NOAA's New Mobile Atmospheric River Observatory (Mobile ARO)

First deployment at Westport, WA for Winter 2009/2010

- target is for first real-time data available by 1 Nov 2009

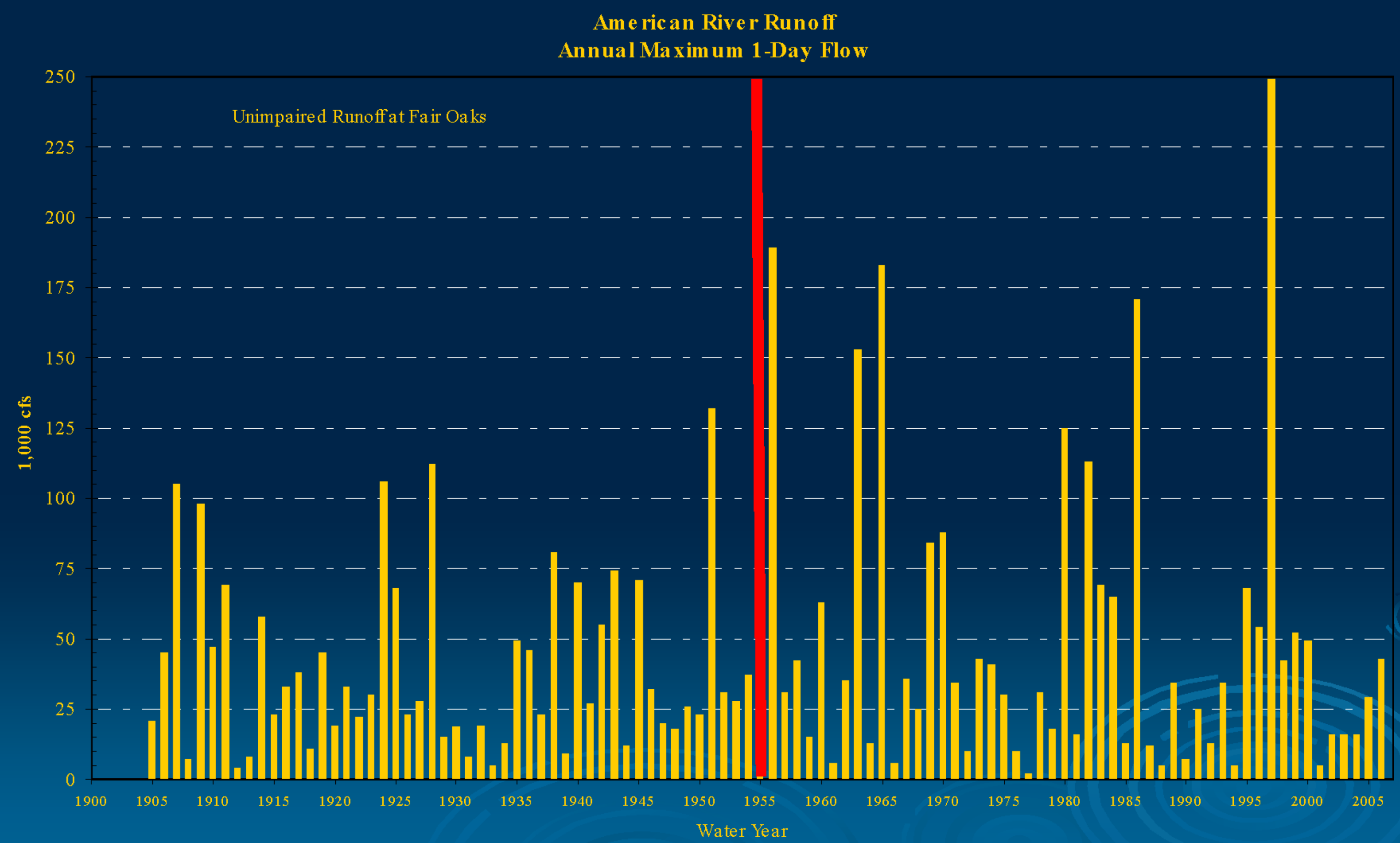
Washington Mobile Atmospheric River Monitoring System Deployment – 1 Nov/09



ARO Instrumentation and Measurements

Instrument	Measure(s)	Vertical Res.	Temporal Res.	Altitude Coverage
915-MHz Wind Profiler/RASS	Wind and Temperature Profiles, Snow Level, BL Depth	60 m, 100 m	Hourly or Sub-hourly	0.15-2+ km in clear air, 0.15-4+ km in storms (winds); 0.15-1+ km (Tv)
S-Band Precip. Profiling Radar (S=PROF)	Precipitation Reflectivity and Velocity Profiles, Snow Level	60 m	30-s	0.13-8+ km in storms
10-m Met Tower	P, T, RH, WS, WD, Solar IR., Net IR, Rainfall	N/A	2-min.	N/A
GPS Receiver	Integrated water vapor	N/A	Hourly or Sub-hourly	N/A
Optical Disdrometer	Velocity and Size Distributions of Precipitation	N/A	2-min.	N/A

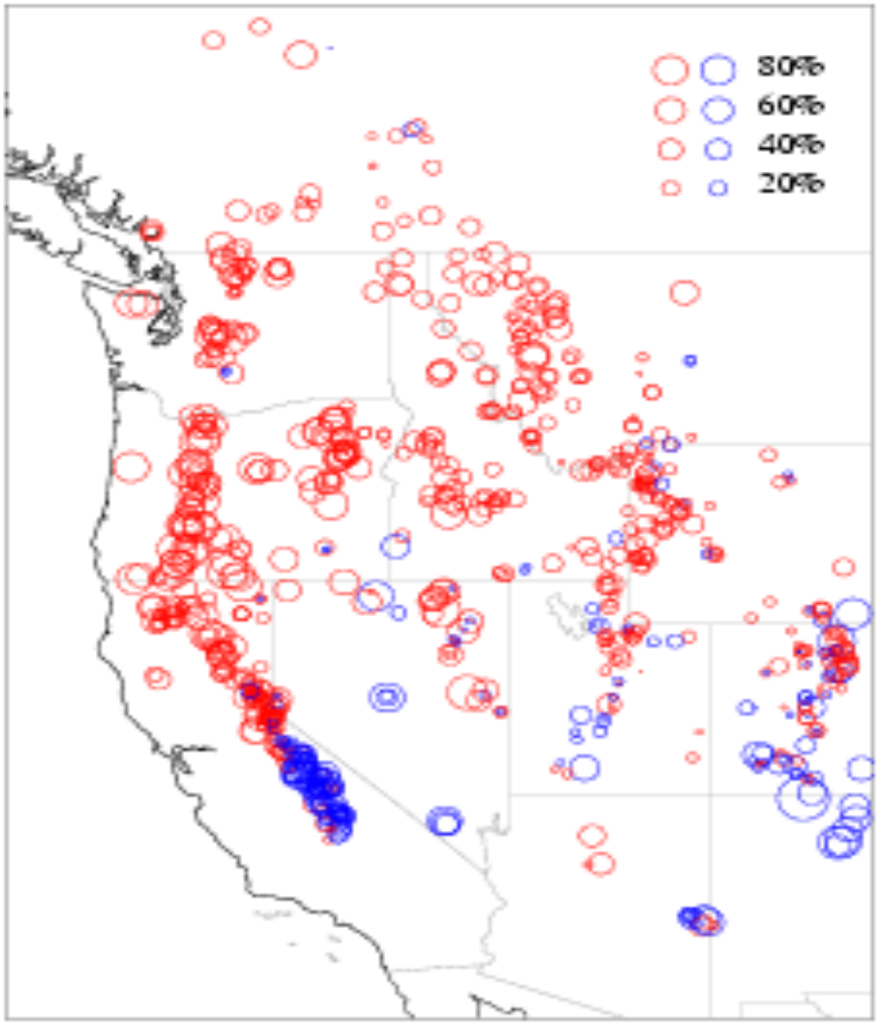
Changes in Peak Flows
American River



Red Line = Construction of Folsom Dam

Lester Snow, CA-DWR

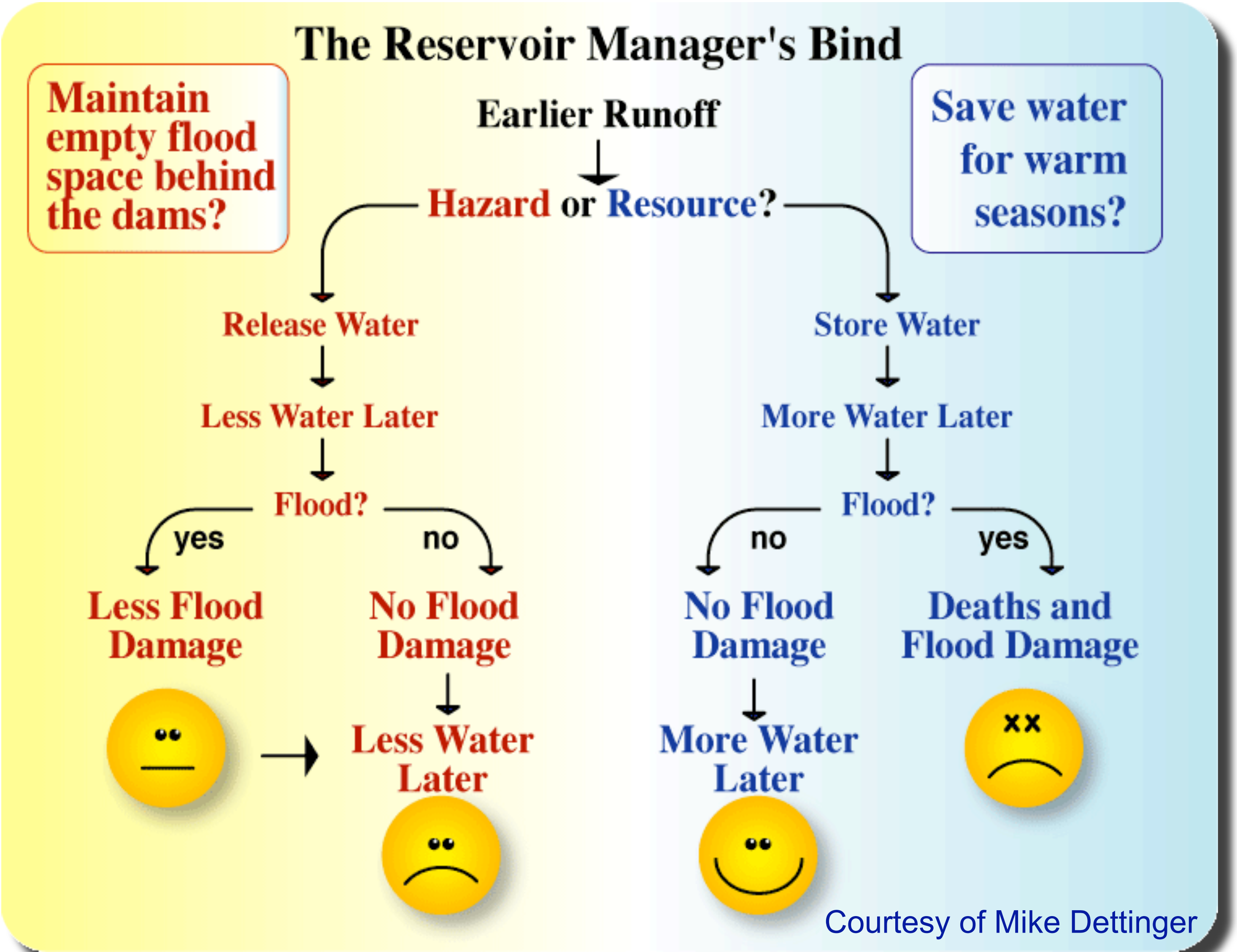
TRENDS (1950-97) in April 1 snow-water content at snow courses



- **Snowmelt supplies about 60-75% of western surface-water supplies, and a roughly equal (or greater) part of western ground-water recharge...**
- **Recent warming trends appear to have caused significant snowpack declines in much of that area**
- **--> Less spring snowpack**

Courtesy of Mike Dettinger

Climate change may put some water managers in a real bind!

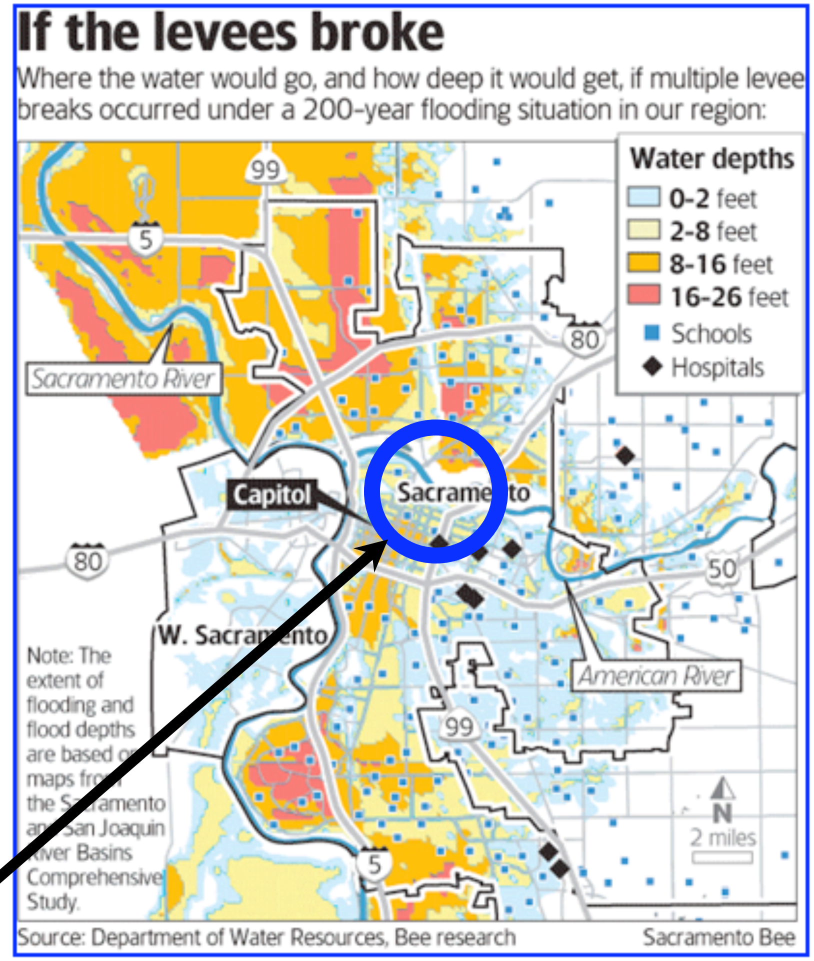


--> Storage & transferability of water supplies will thus be at a premium.

The Sacramento Flood Risk

- Complex water resource management issues in an urban area with large societal impacts
  - –Large demand for water/hydropower
  - –Threat of devastating flood

Photo by Bryan Patrick, Sacramento Bee



Several feet inundation possible in downtown Sacramento