Development of Prototype National Water Model Soil Moisture Products for Drought Monitoring

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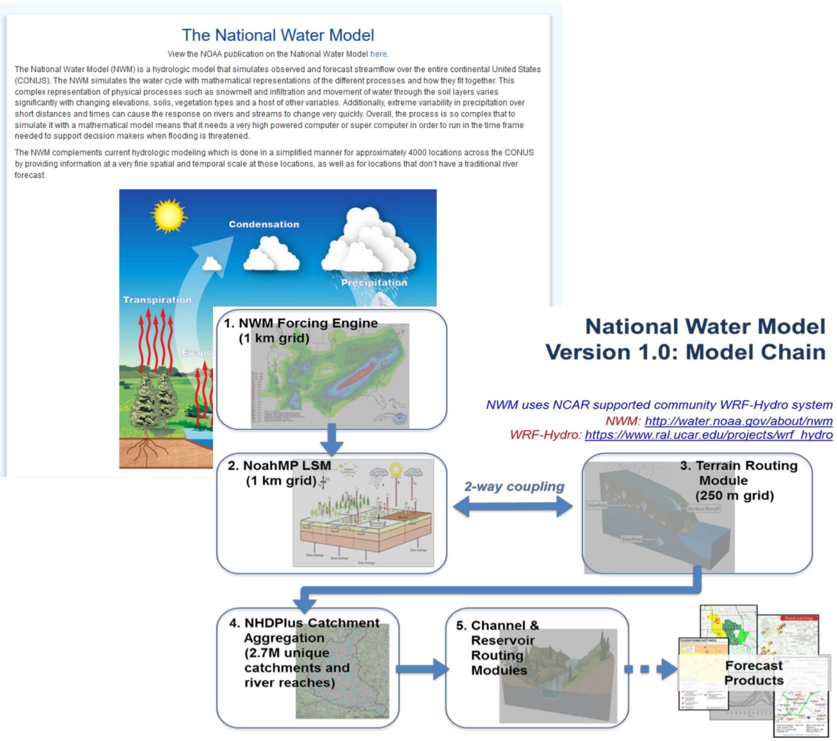
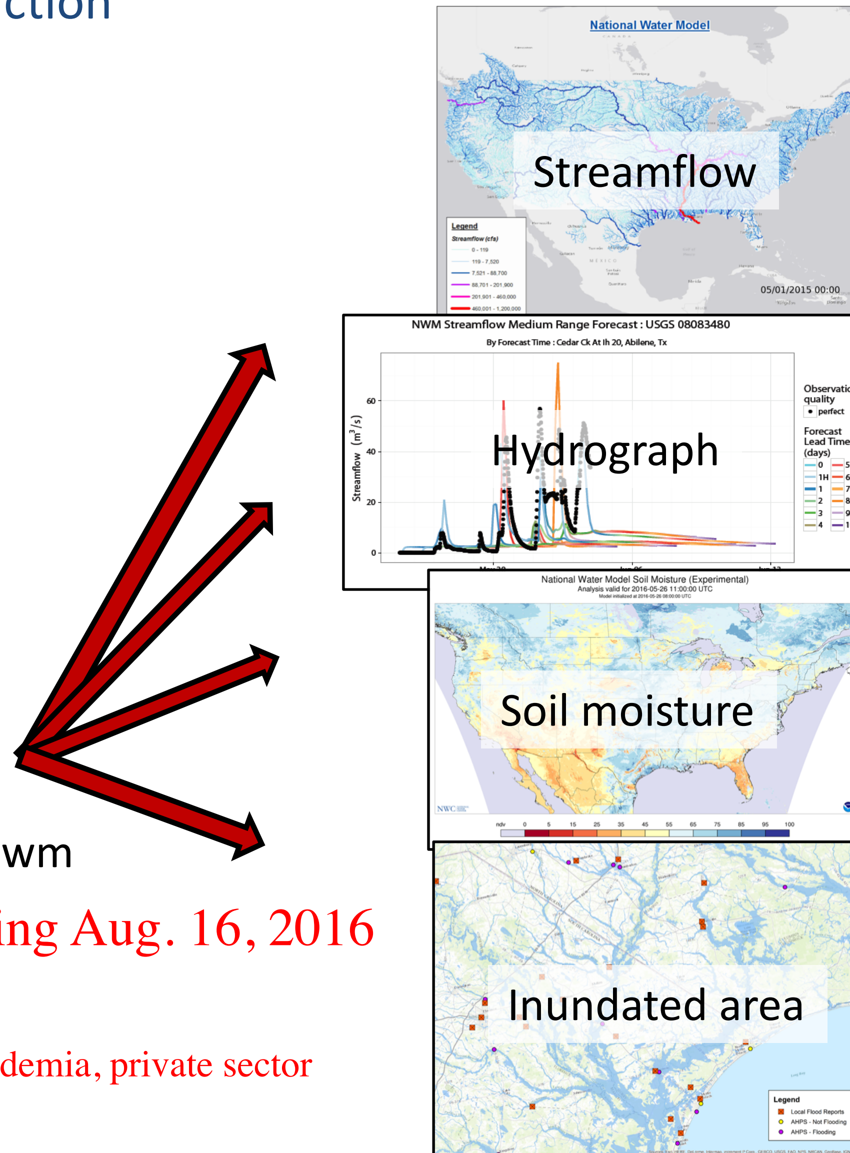
Funding from NOAA CPO and NIDIS

The National Water Model

Development Team: NCAR/RAL, NOAA/NWS/OWP , USGS, CUAHSI, Universities

Sponsor: NOAA Office of Water Prediction





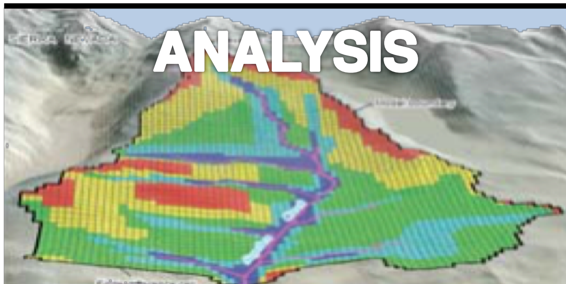
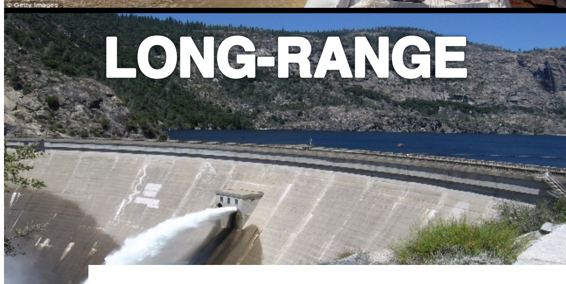
http://water.noaa.gov/about/nwm

System became fully operational beginning Aug. 16, 2016

- Real-time verification since June 2016 (Rwrfhydro)
- Multiple operational products created by NOAA, academia, private sector

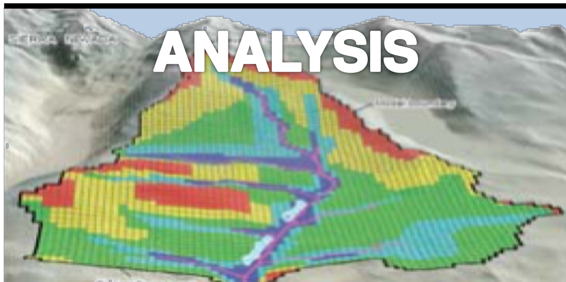
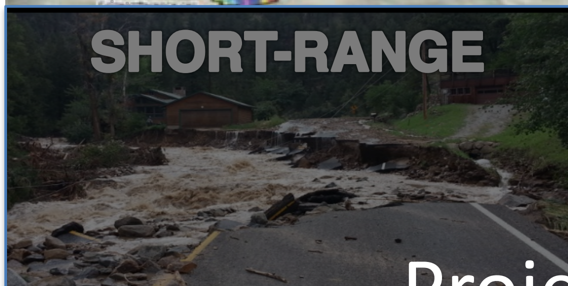
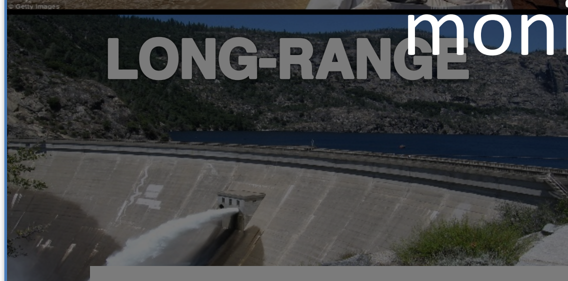
Slide courtesy David Gochis (NCAR)

NWM Operational Cycles:

	Cycling	Forecast	Met Forcing	Outputs
 ANALYSIS	Hourly	-3 - 0 hrs	MRMS QPE and HRRR/RAP blend	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 SHORT-RANGE	Hourly	1 – 18 hrs	Downscaled HRRR/RAP Blend	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 MEDIUM-RANGE	4x Daily	to 10 days	Downscaled GFS	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 LONG-RANGE	Daily x 16 ensembles	to 30 days	Downscaled & NLDAS2 Bias-Corrected CFS	1-km spatial fluxes (water & energy); NHDPlus channel routing

Slide courtesy David Gochis (NCAR)

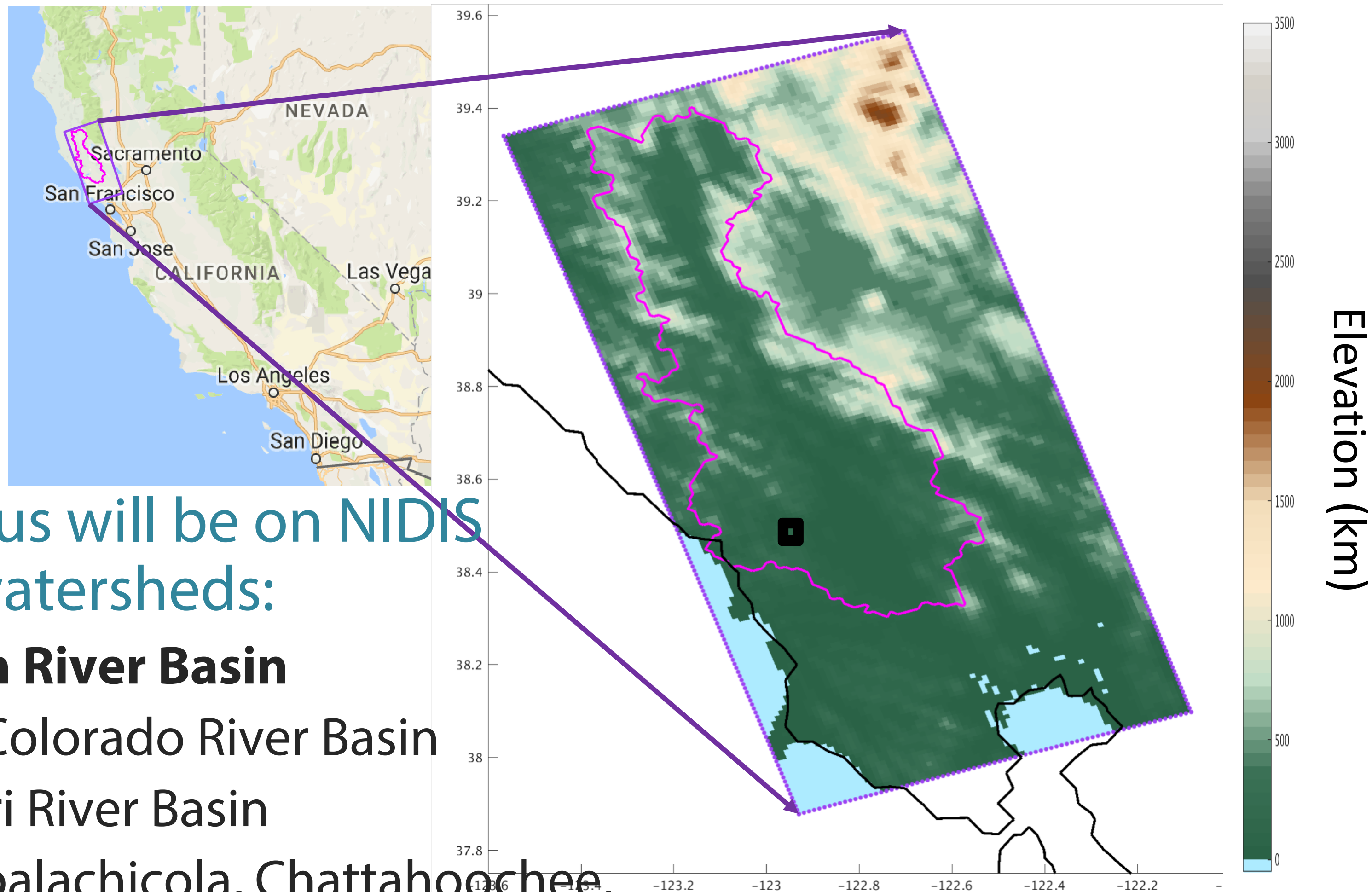
NWM Operational Cycles:

	Cycling	Forecast	Met Forcing	Outputs
 ANALYSIS	Hourly	-3 - 0 hrs	MRMS QPE and HRRR/RAP blend	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 SHORT-RANGE	Hourly	1 – 18 hrs	Downscaled HRRR/RAP Blend	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 MEDIUM-RANGE	4x Daily	to 10 days	Downscaled GFS	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 LONG-RANGE	Daily x 16 ensembles	to 30 days	Downscaled & NLDAS2 Bias-Corrected CFS	1-km spatial fluxes (water & energy); NHDPlus channel routing

Project goal: Create products from the NWM analysis outputs for drought monitoring purposes.

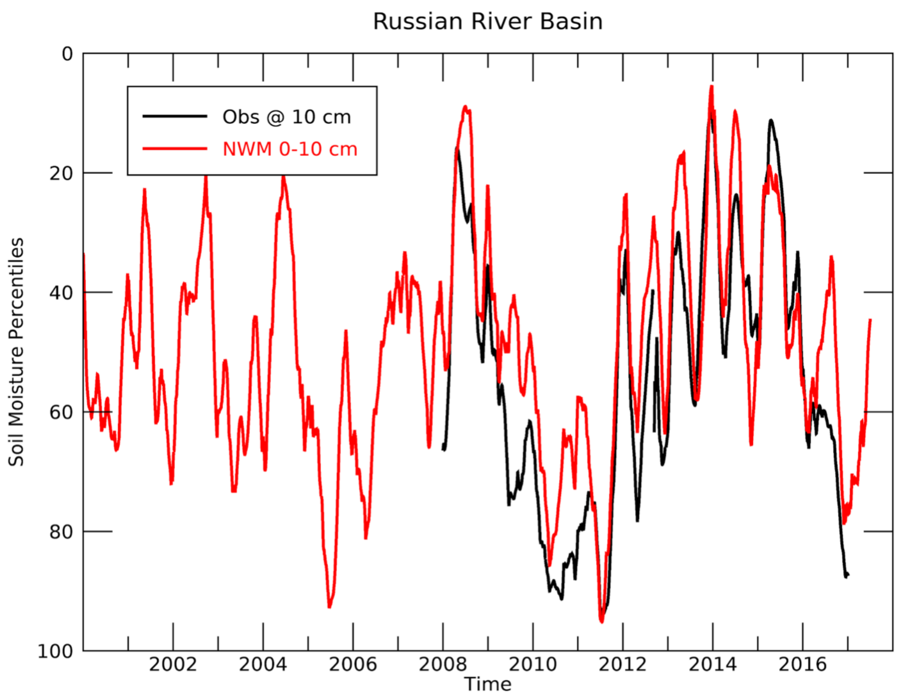
Slide courtesy David Gochis (NCAR)

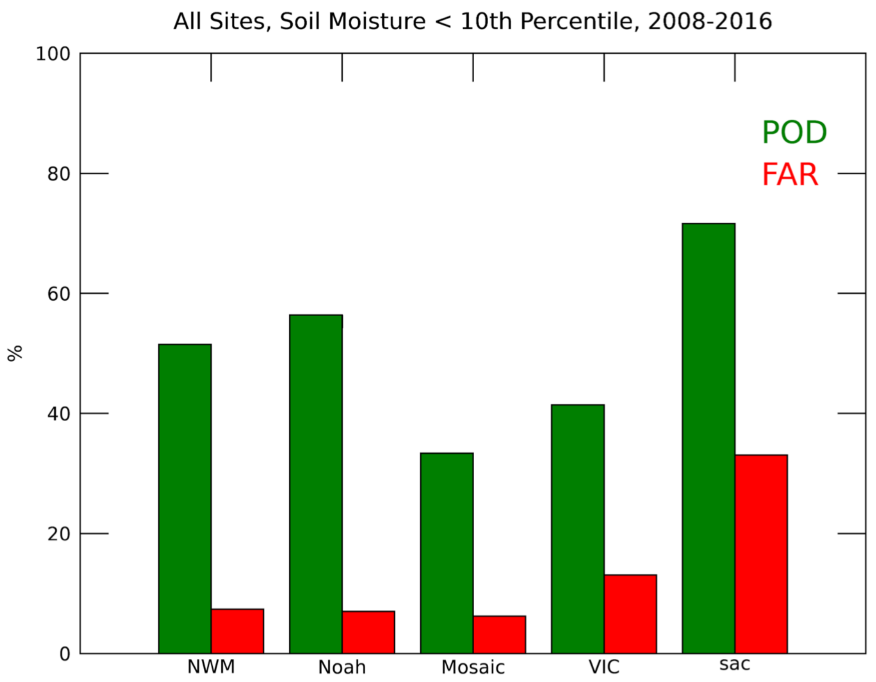
Demonstration regions



- Initial focus will be on NIDIS priority watersheds:
  - **Russian River Basin**
  - Lower Colorado River Basin
  - Missouri River Basin
  - ACF (Apalachicola, Chattahoochee, and Flint) River Basin

Comparison against in situ observations





2x2 Contingency Table		Event Observed	
		Yes	No
Event Forecast	Yes	a (hits)	b (false alarms)
	No	c (misses)	d (correct negatives)

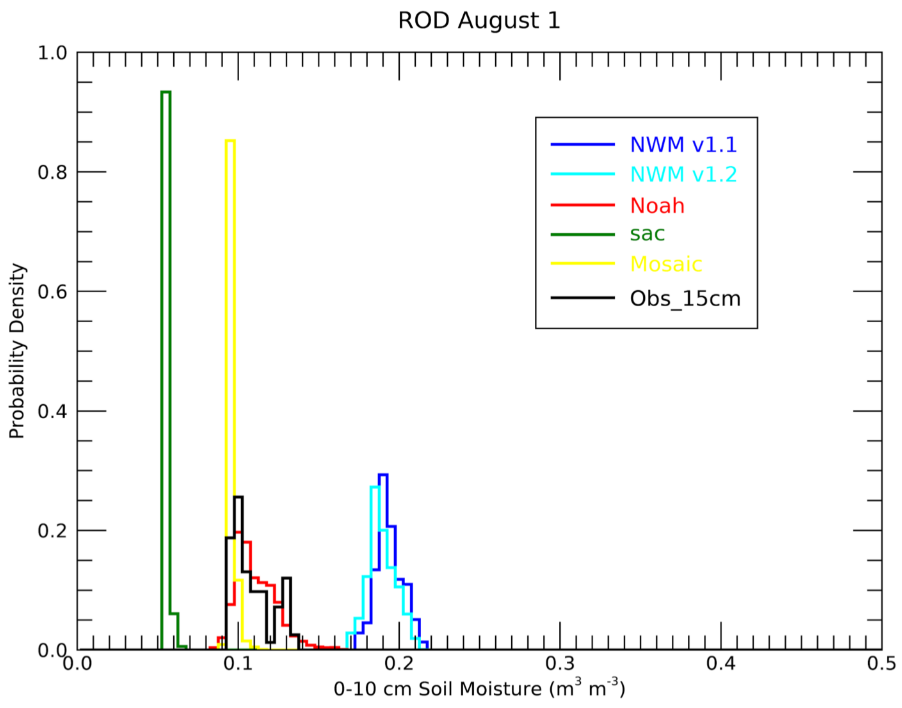
POD = a/(a+c)

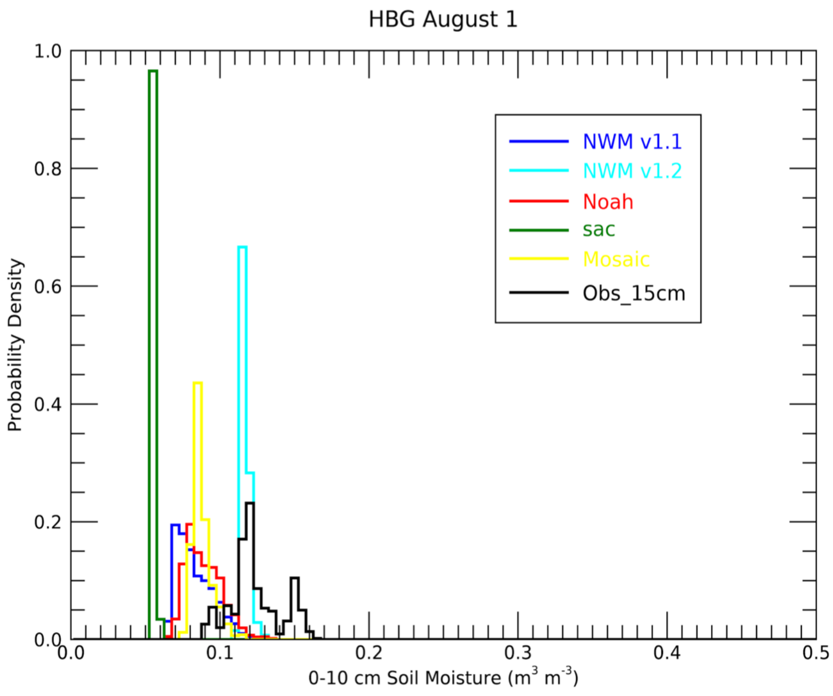
FAR = b/(a+b)

Confronting challenges: Version changes

Probability Density comparison at 0-10 cm layer in dry season

- v1.1 and v1.2 agree very well at Rio Nido (ROD) but biased wet from observations
- V1.1 and v1.2 disagree at Healdsburg (HBG) with v1.2 in better agreement

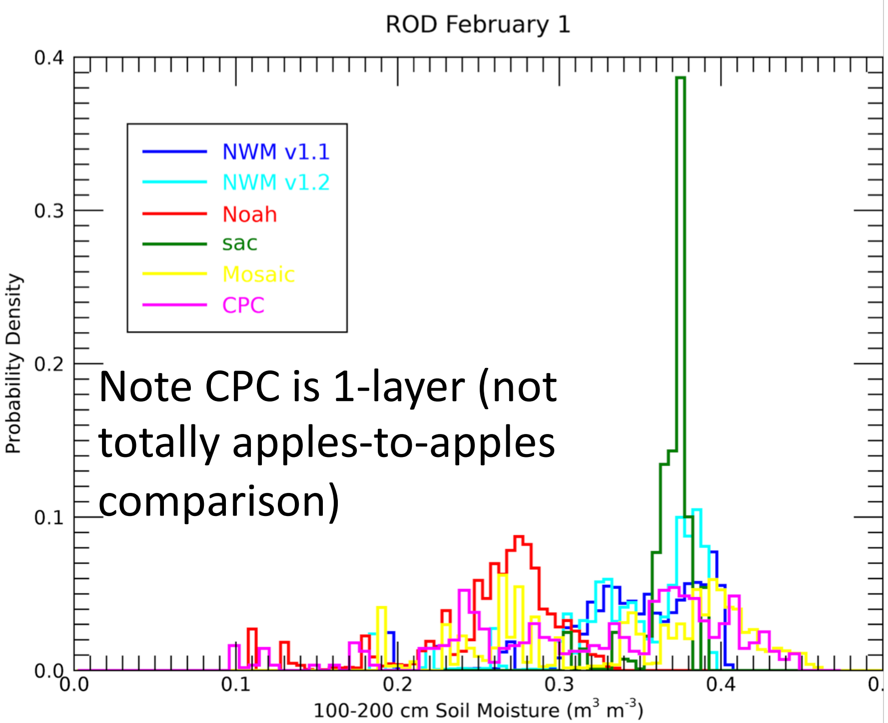




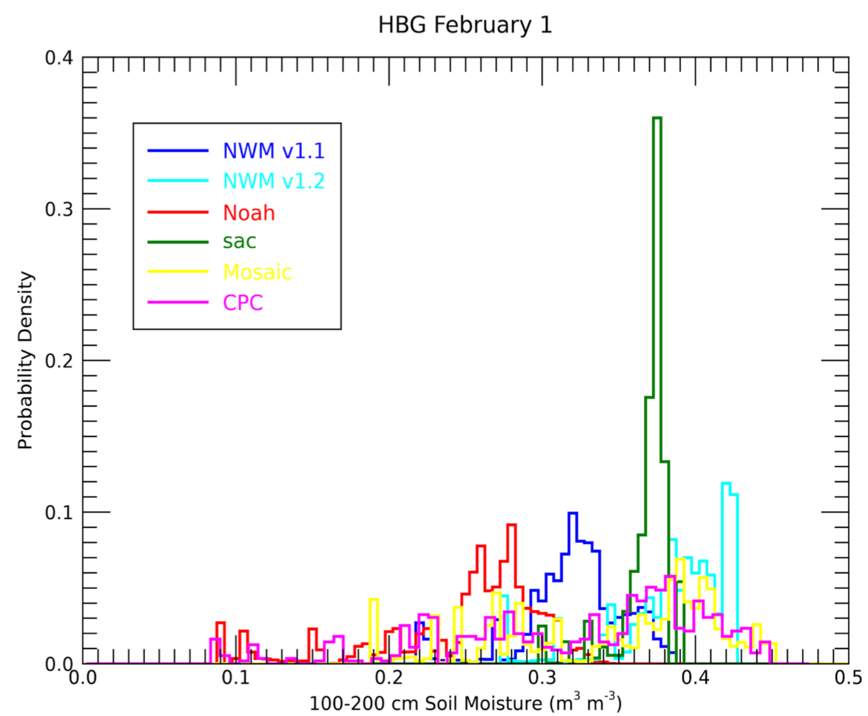
Confronting challenges: Version changes

Probability Density comparison at 100-200 cm in wet season

- Broader distributions during the wet season.
- Similar result for v1.1 to v1.2 comparison with similar structure at ROD but biased results at HBG.

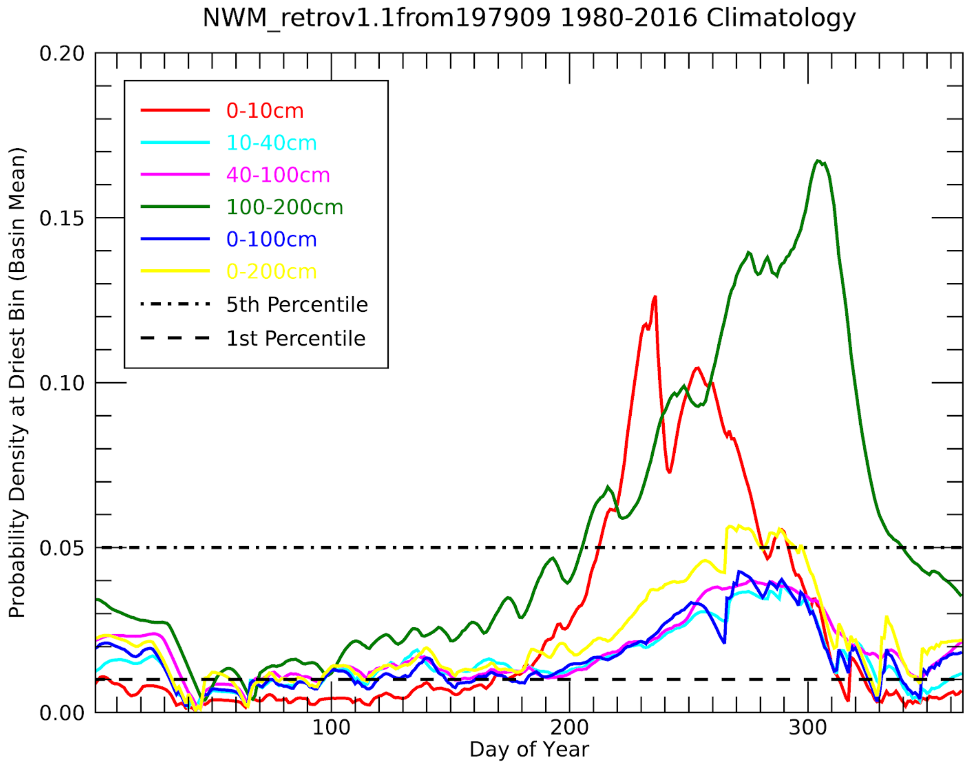


Note CPC is 1-layer (not totally apples-to-apples comparison)



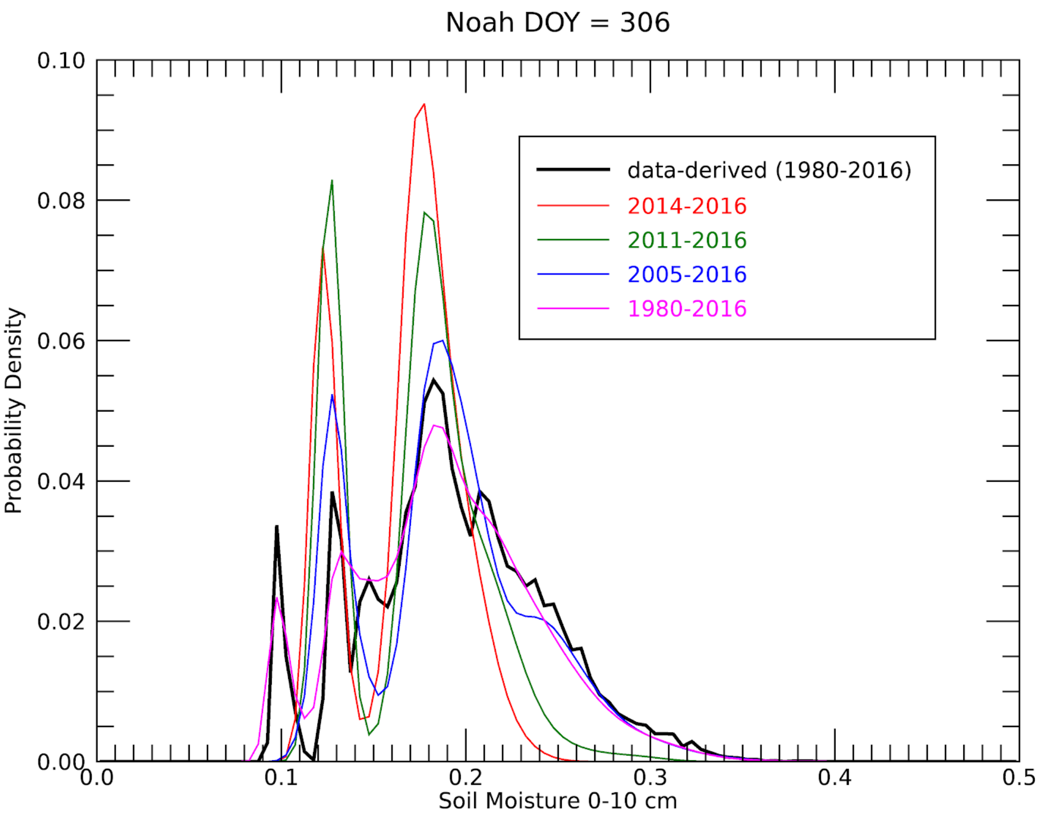
Thanks to Yun Fan from CPC for the NLDAS-forced leaky bucket output

Confronting challenges: narrow PDFs



- In some locations and depths, the climatological PDF is too narrow to be able to distinguish precipitation extremes

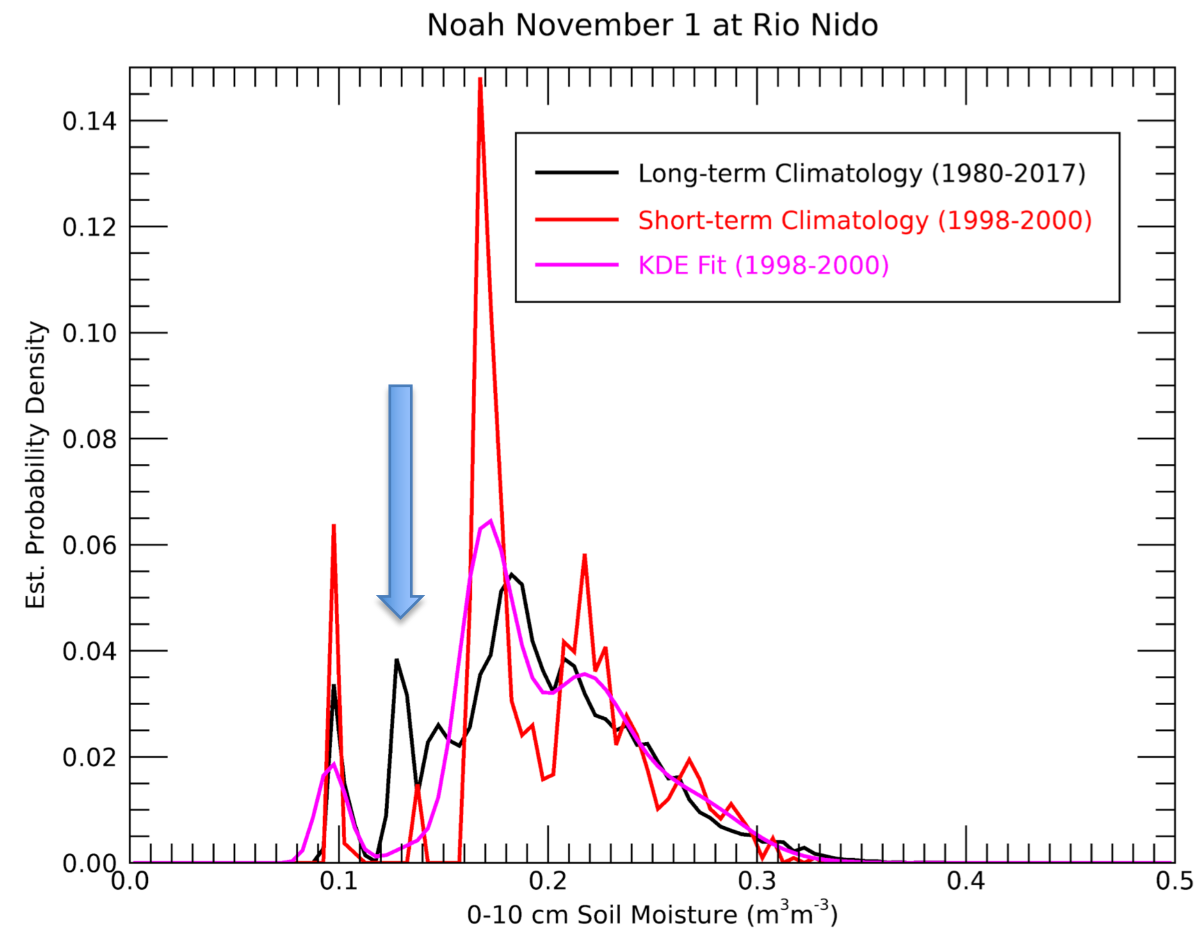
Confronting challenges: short historical period data



The NWM analysis cycle is forced with a blend of operational forcings (HRRR model and MRMS). These forcings are only available post ~2014.

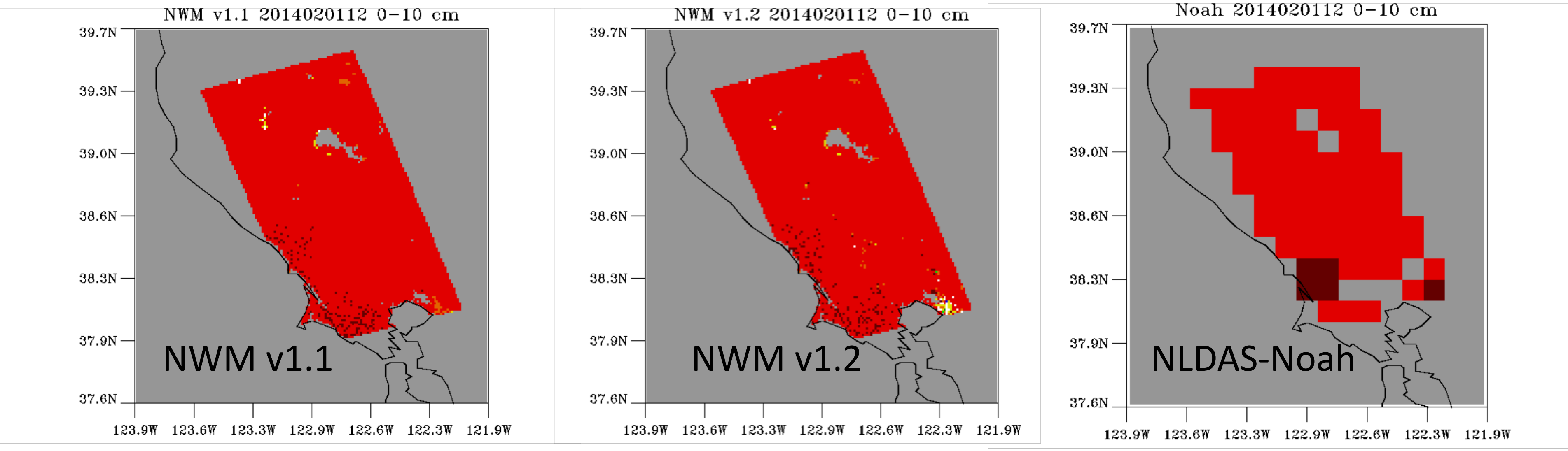
Estimation of reference climatology with KDE

Kernel Density Estimation (KDE) method used to fit short-term climatology.



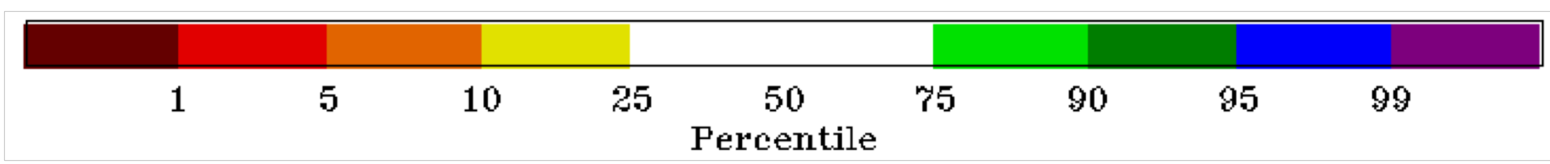
0-10 cm layer soil moisture PDFs for both long and short term for one grid cell at Rio Nido in the Russian River Basin.

Example products: 0-10 cm soil moisture percentiles

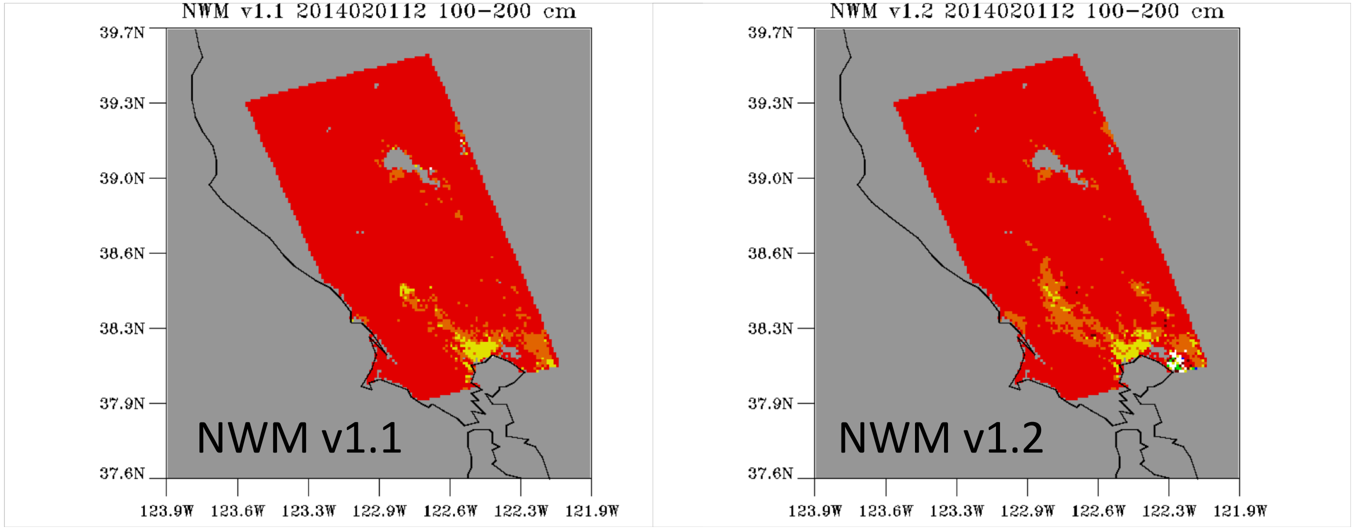


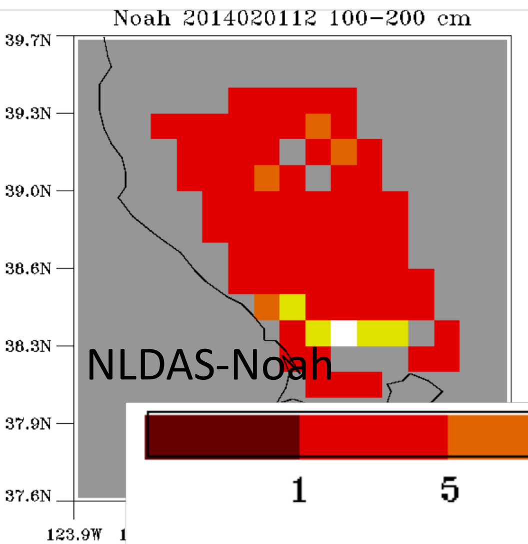
February 1, 2014

- Nearing peak of exceptional drought later in 2014



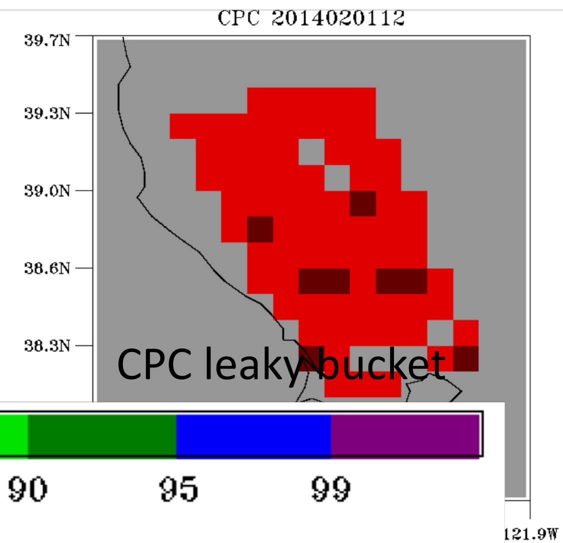
Example products: 100-200 cm SM percentiles

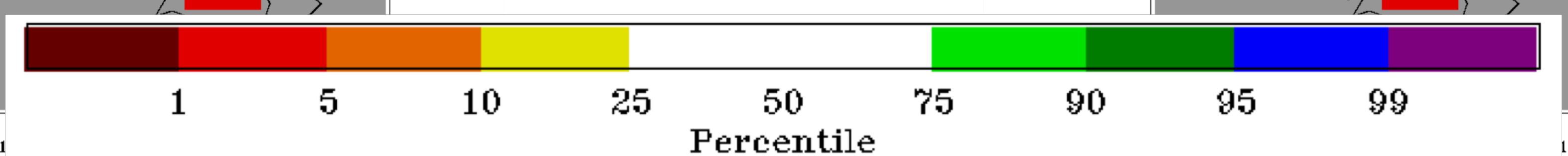




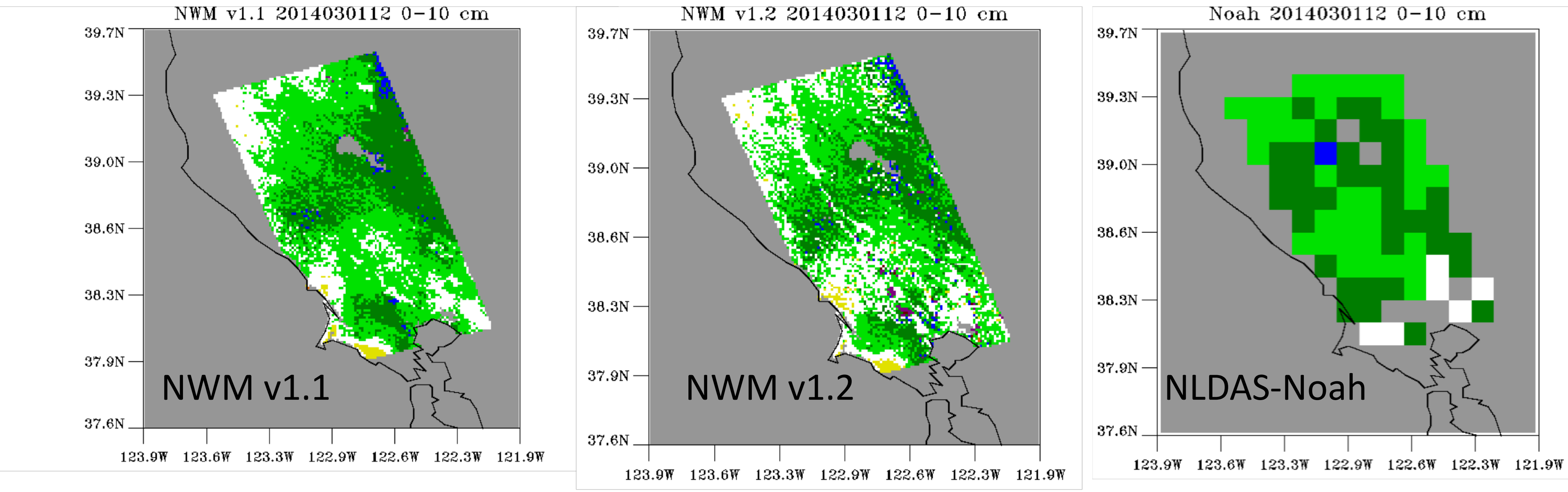
February 1, 2014

- 100-200 cm lower soil layer



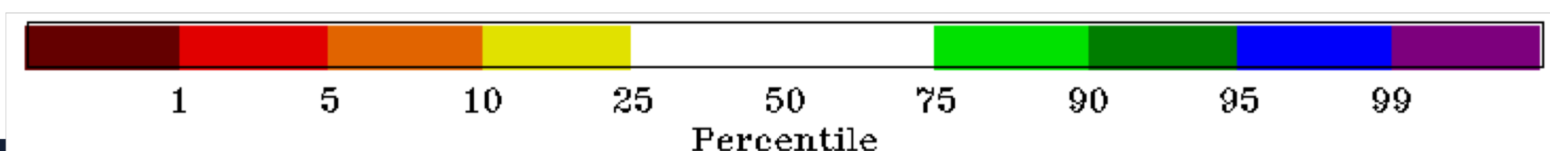


Example products: 0-10 cm SM percentiles

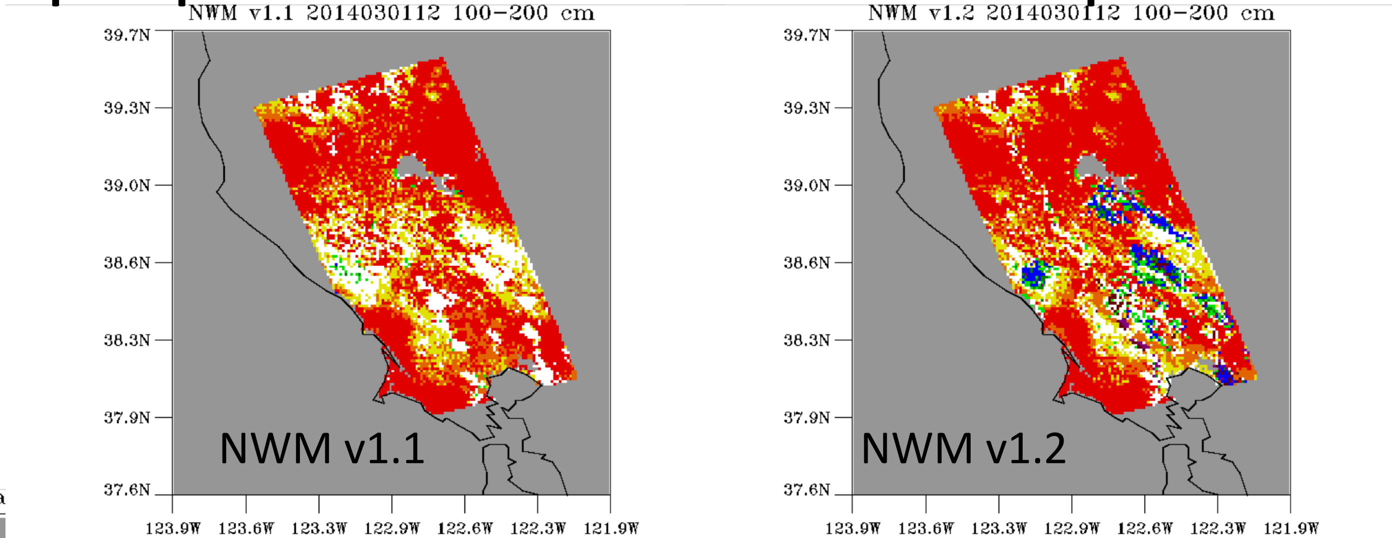


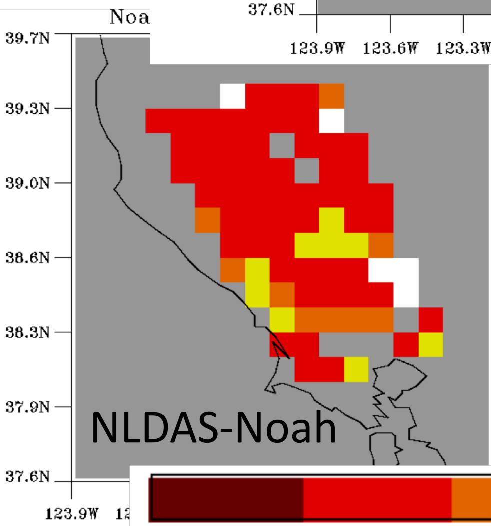
March 1, 2014

- 0-10 cm upper soil layer following rainfall on February 27th.
- Note Russian river signature in v1.2 and extreme wet regions



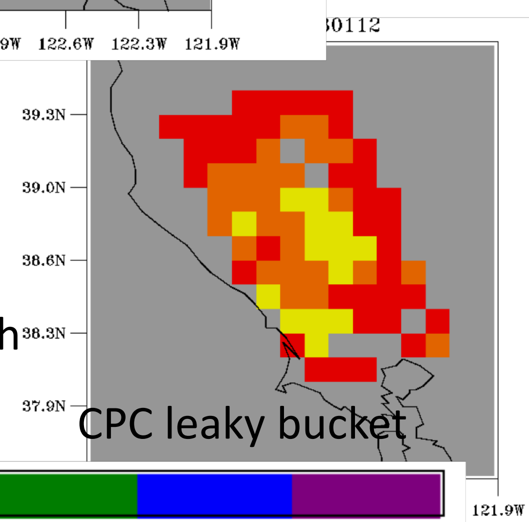
Example products: 100-200 cm SM percentiles

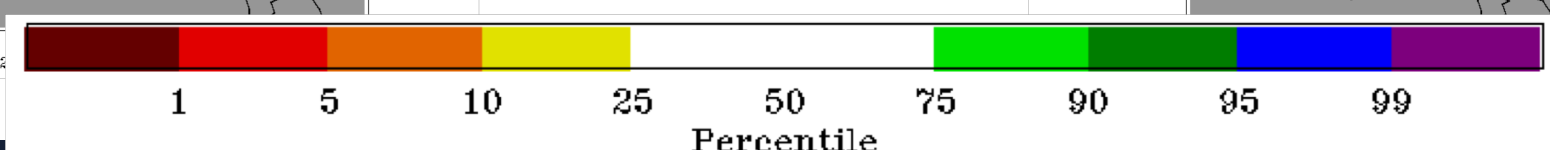




March 1, 2014

- 100-200 cm lower soil layer following rainfall on February 27th
- V1.2 has intense wet areas





Thanks!

Email: mimi.hughes@noaa.gov

NWM: http://water.noaa.gov/about/nwm

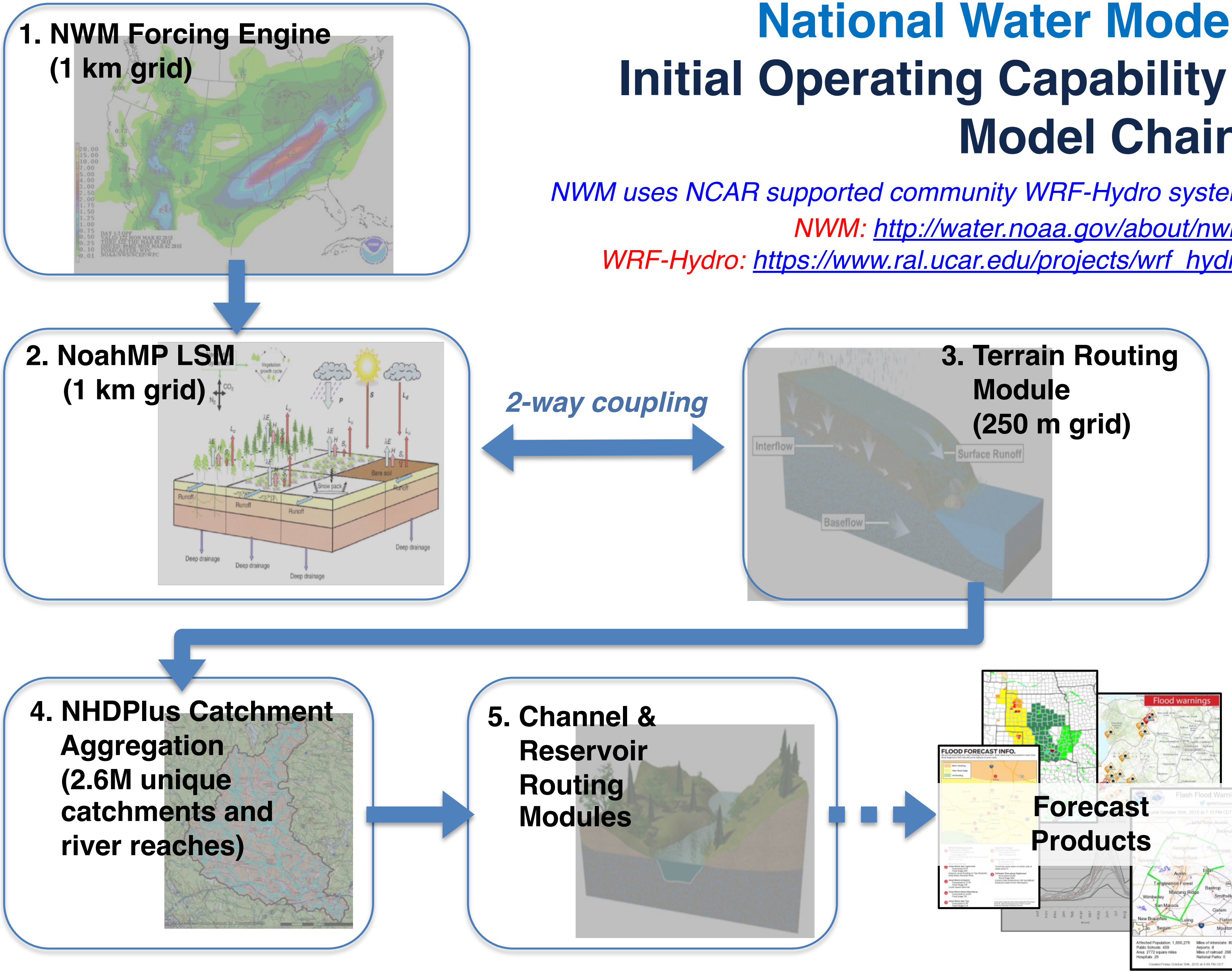
Funding from NOAA CPO and NIDIS

National Water Model
Initial Operating Capability: Model Chain

NWM uses NCAR supported community WRF-Hydro system

NWM: http://water.noaa.gov/about/nwm

WRF-Hydro: https://www.ral.ucar.edu/projects/wrf_hydro



Slide courtesy David Gochis (NCAR)

The National Water Model Version 1: Technical Specs

Development Team: NCAR/RAL, NOAA/OWP/NWC, USGS, CUAHSI, Universities
Sponsor: NOAA Office of Water Prediction

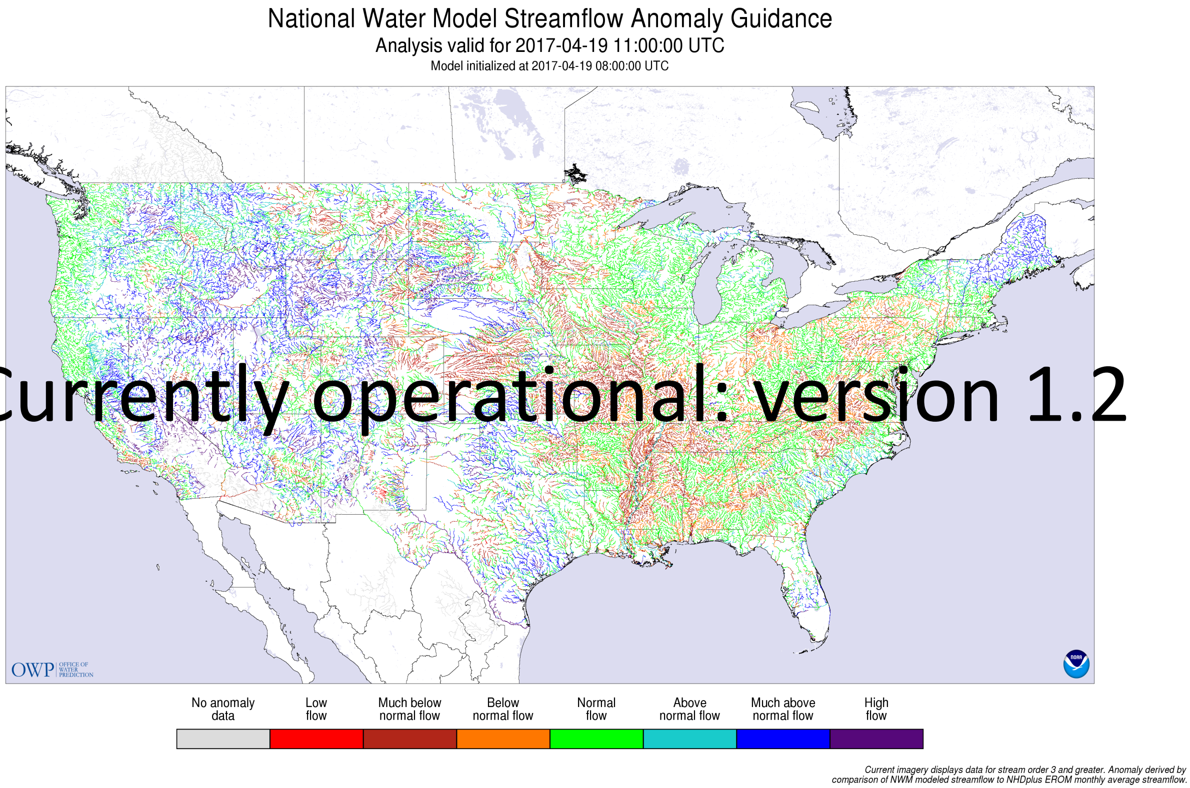
Data Throughput:

- Input data per day: 4.45 Terabytes
- Output data per day: 3 Terabytes
- # of river channels: 2.7 million
- # of reservoirs: 1,260
- Total # of computational elements: ~360,000,000

Model Details:

- Number of lines of code: 74,740
- Computer usage: > 100,000 cpu-hours per day

National Streamflow Anomaly Map



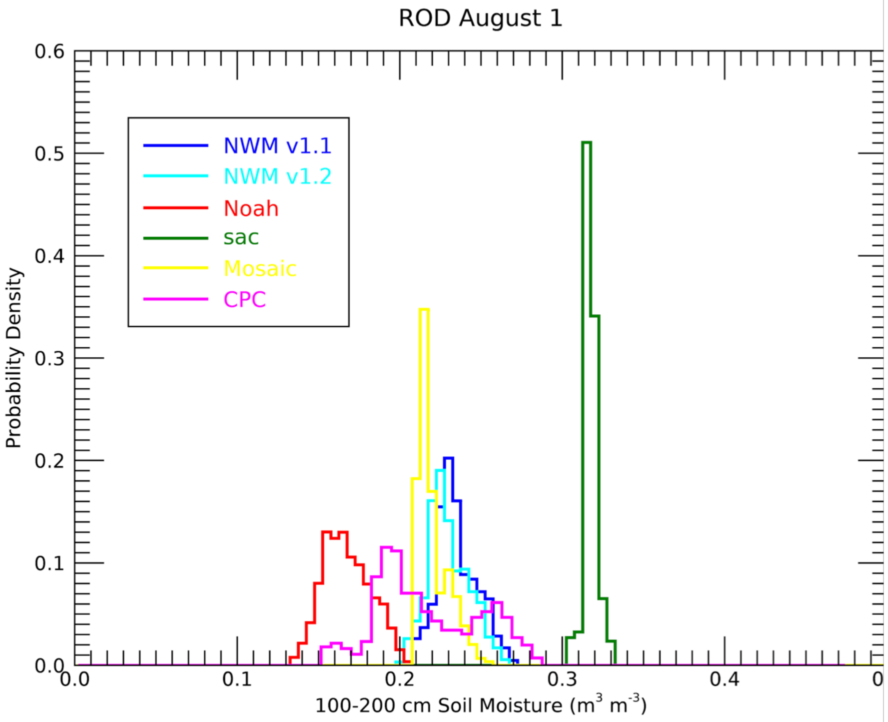
Currently operational: version 1.2

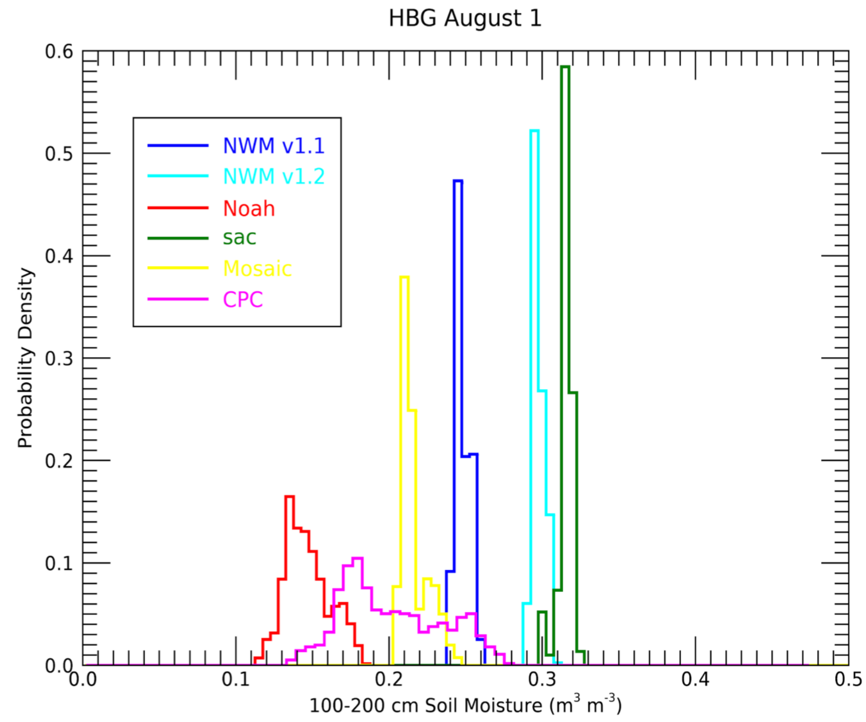
Available online at: *http://water.noaa.gov/tools/nwm-image-viewer*

Slide courtesy David Gochis (NCAR)

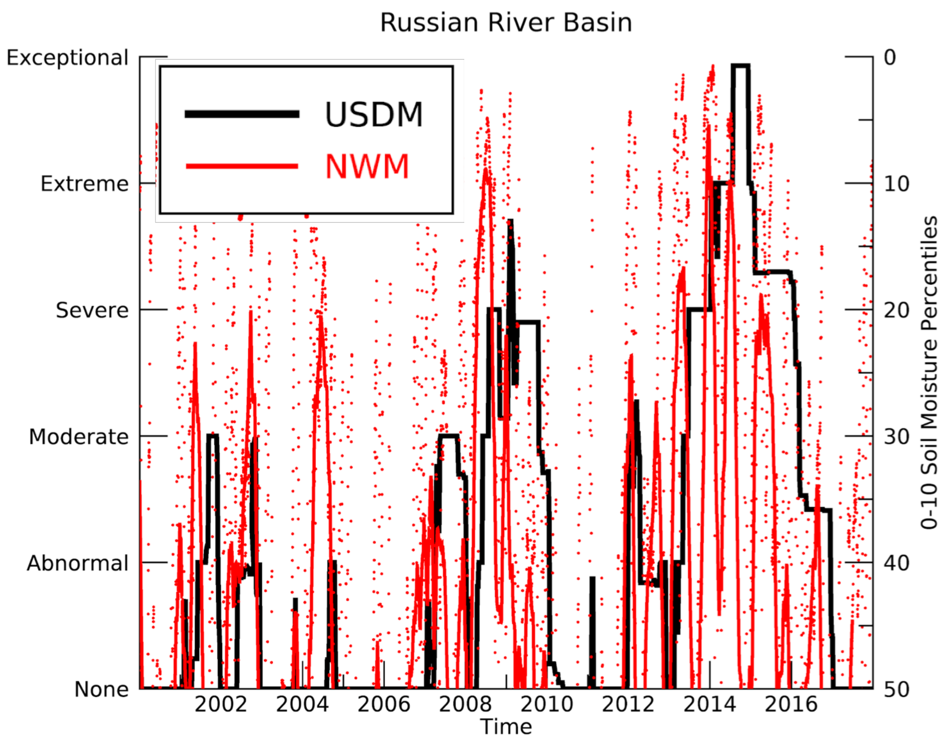
Probability Density comparison at 100-200 cm in dry season

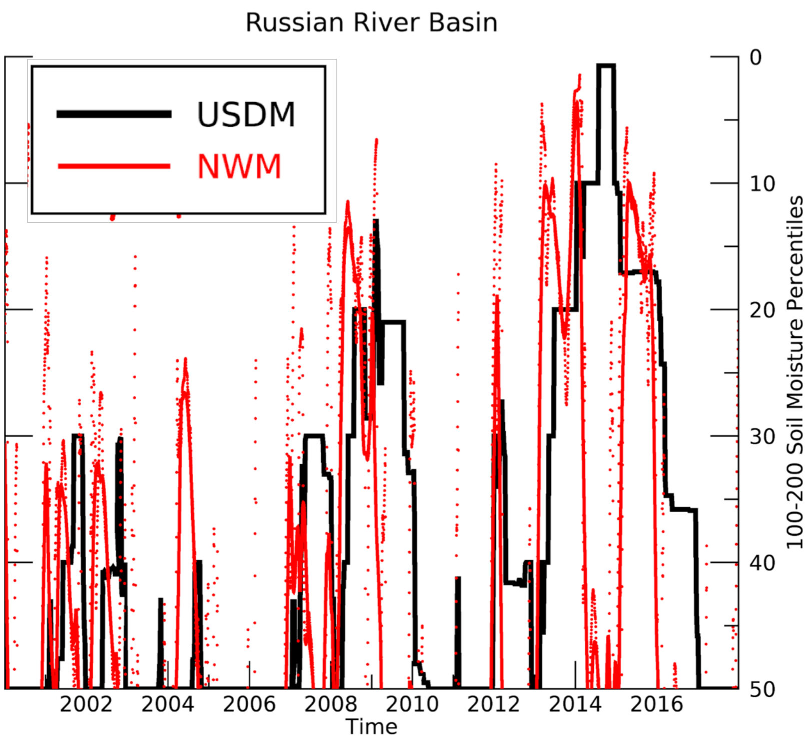
- v1.1 and v1.2 agree well at ROD location but not at HBG
- CPC generally shows broader distribution than models

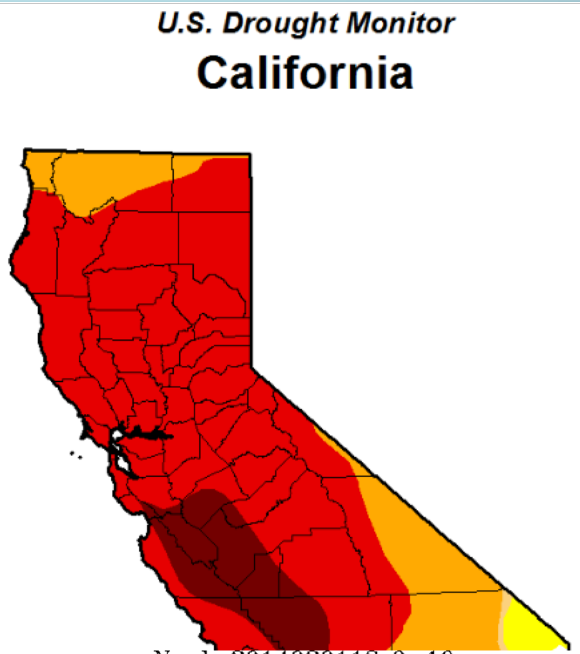


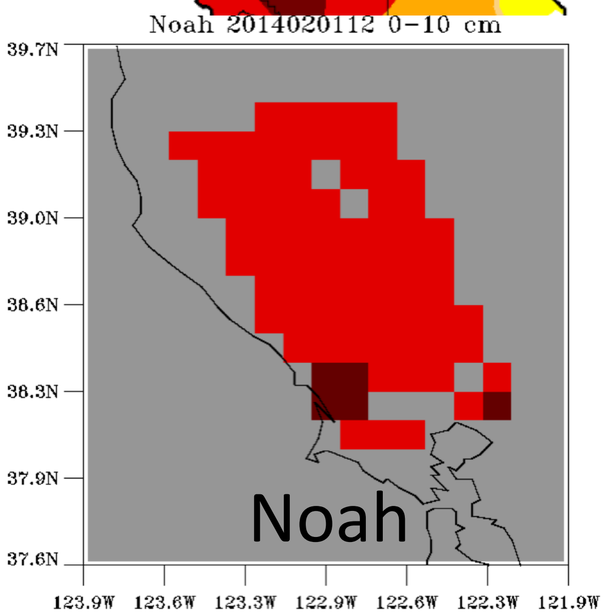


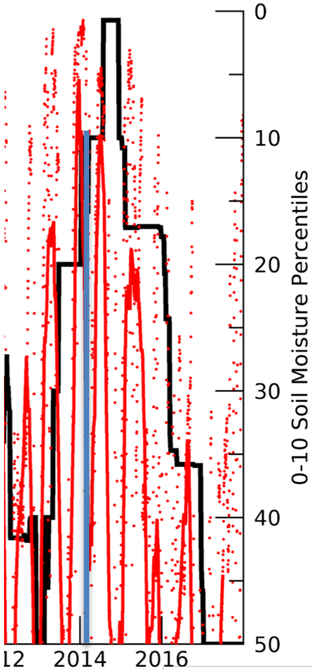
Comparison against USDM

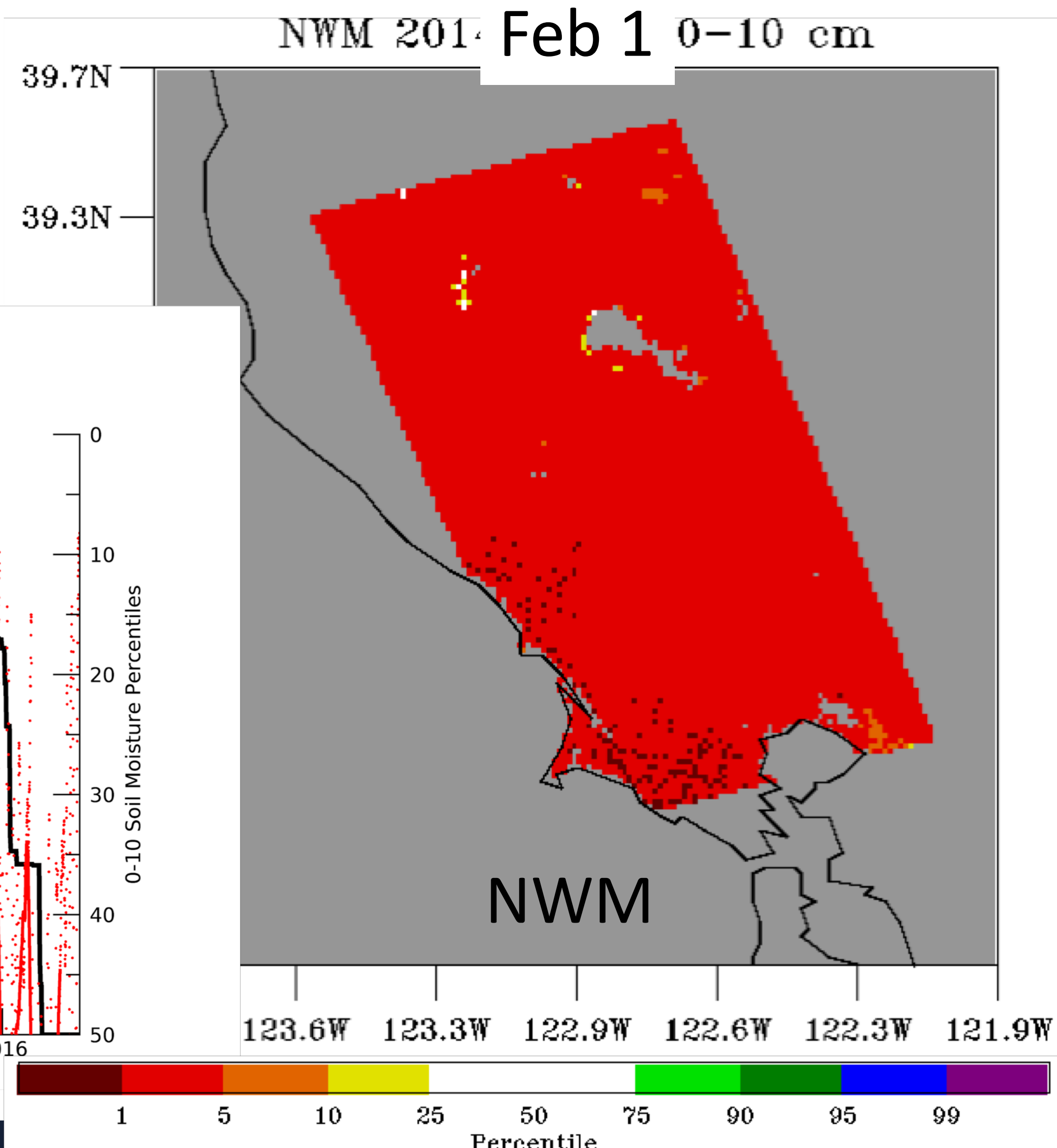


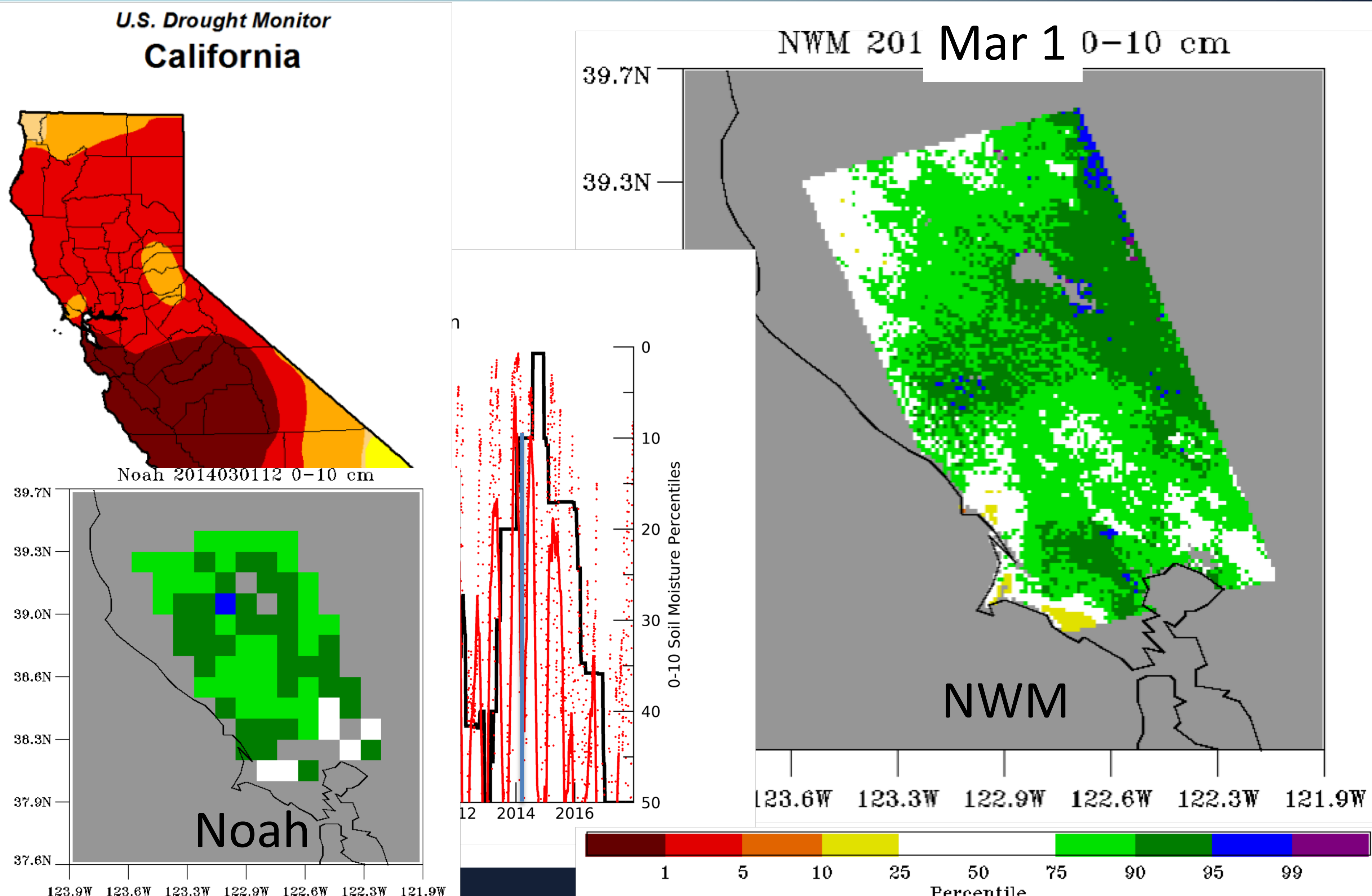


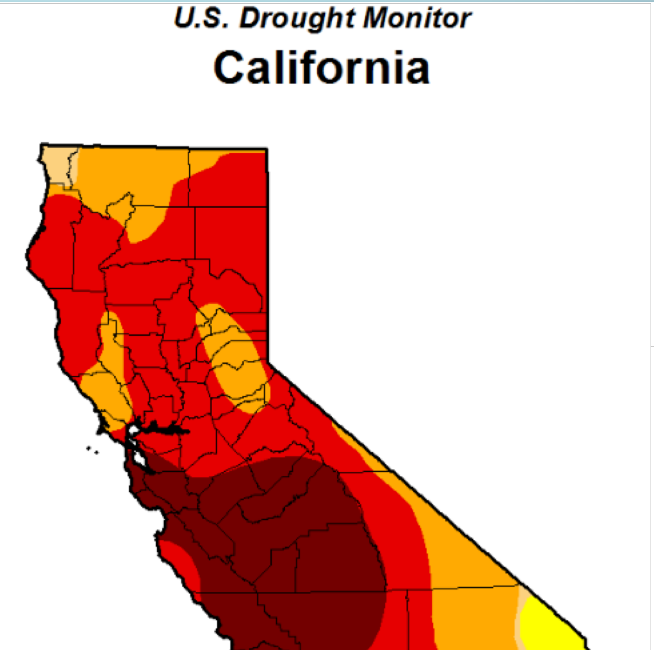

U.S. Drought Monitor
California

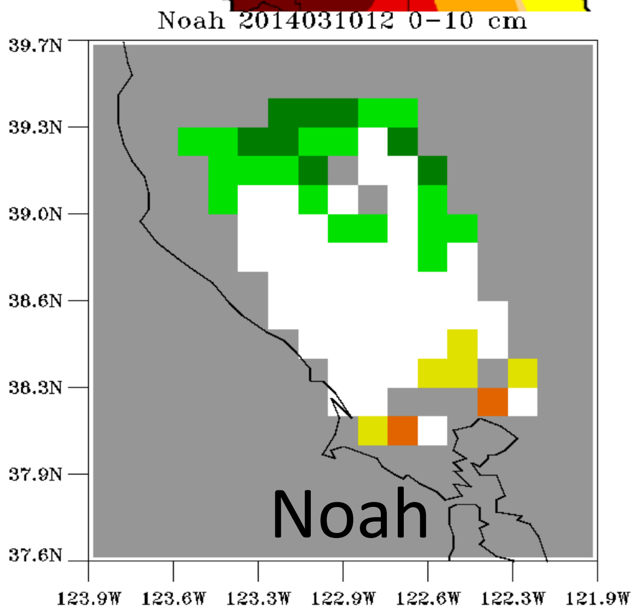

Noah 2014020112 0–10 cm
39.7N
39.3N
39.0N
38.6N
38.3N
37.9N
37.6N
123.9W 123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
Noah


0-10 Soil Moisture Percentiles
0
10
20
30
40
50
2014
2016


NWM 201 Feb 1 0–10 cm
39.7N
39.3N
123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
NWM
1 5 10 25 50 75 90 95 99
Percentile


U.S. Drought Monitor
California
Noah 2014030112 0–10 cm
39.7N
39.3N
39.0N
38.6N
38.3N
37.9N
37.6N
123.9W 123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
Noah
0-10 Soil Moisture Percentiles
0
10
20
30
40
50
12 2014 2016
NWM 201 Mar 1 0–10 cm
39.7N
39.3N
123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
NWM
1 5 10 25 50 75 90 95 99
Percentile


U.S. Drought Monitor
California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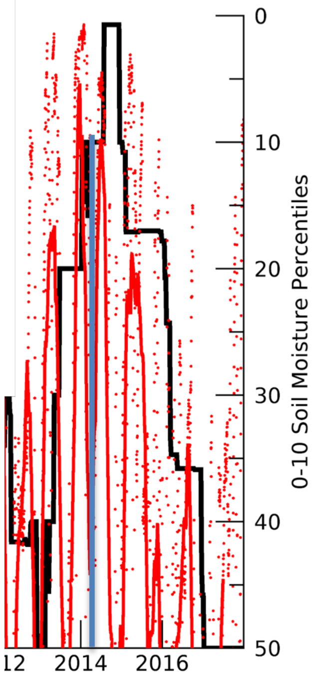
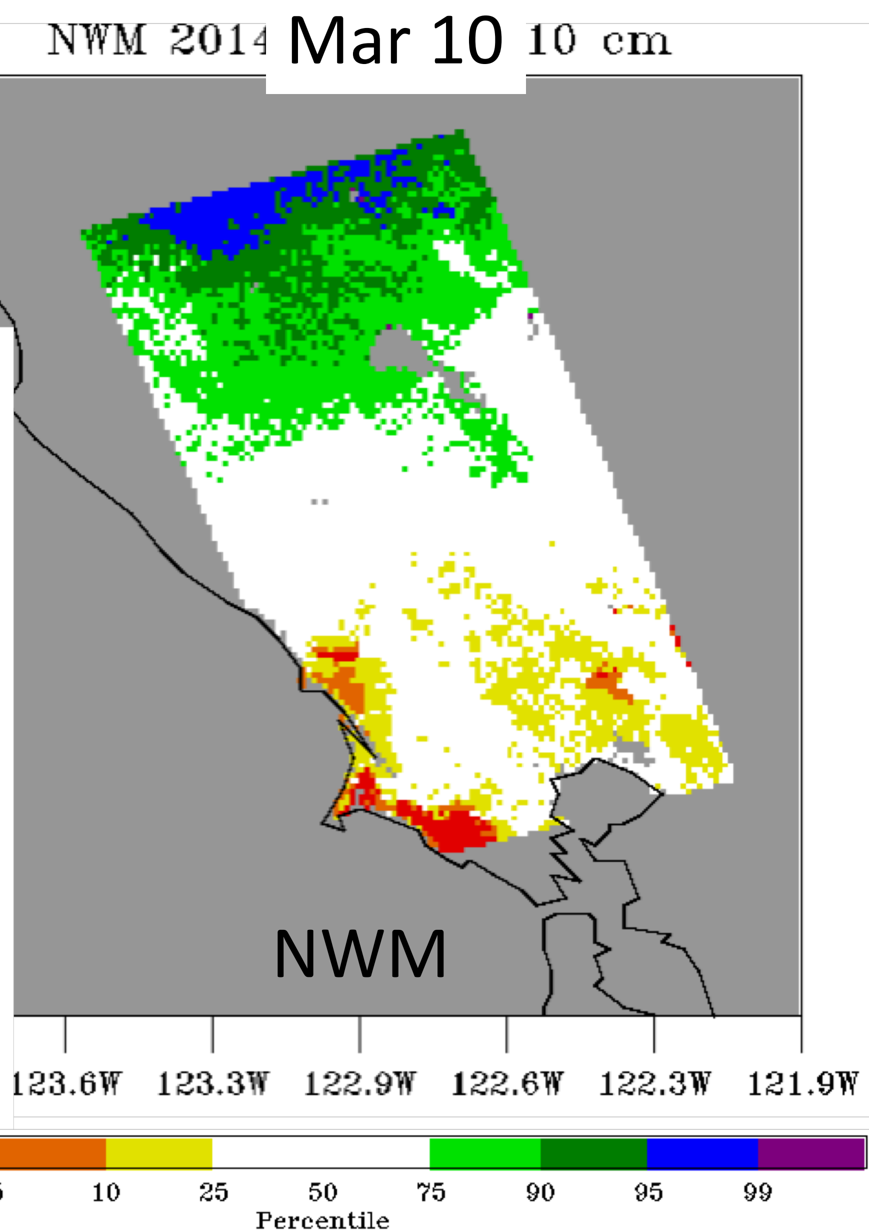
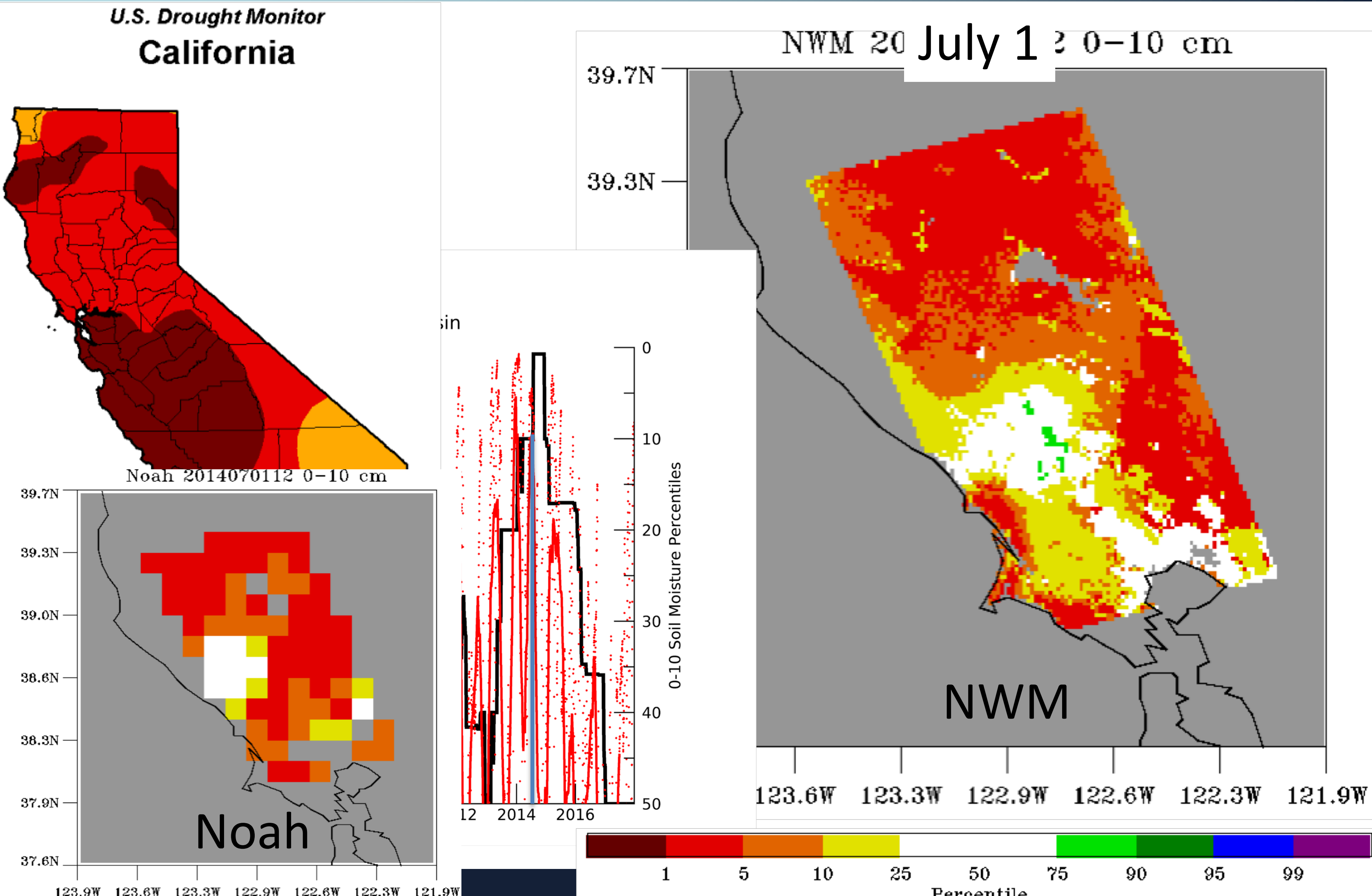
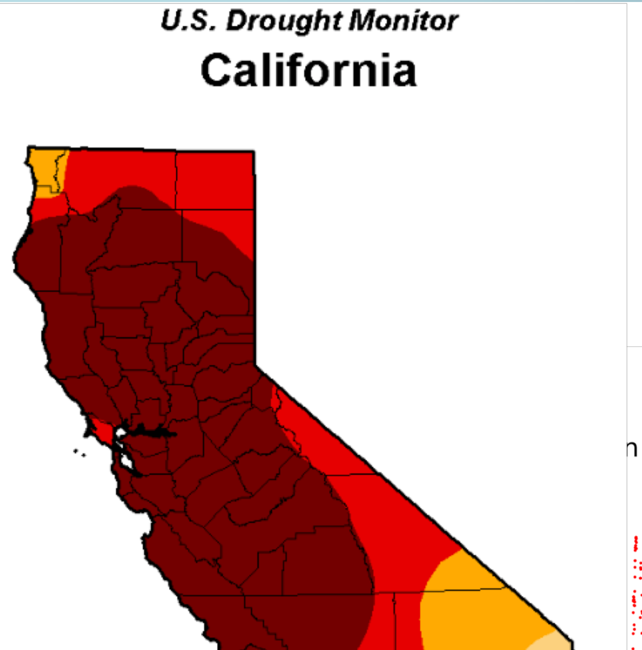
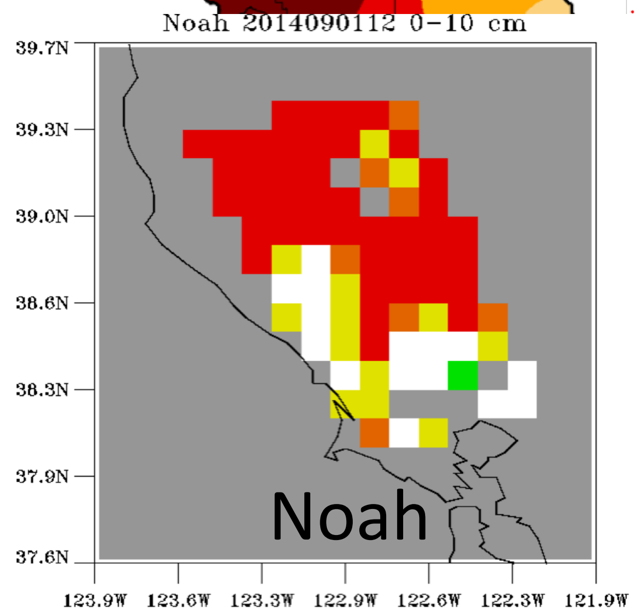
39.3N
39.0N
38.6N
38.3N
37.9N
37.6N
123.9W 123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
Noah

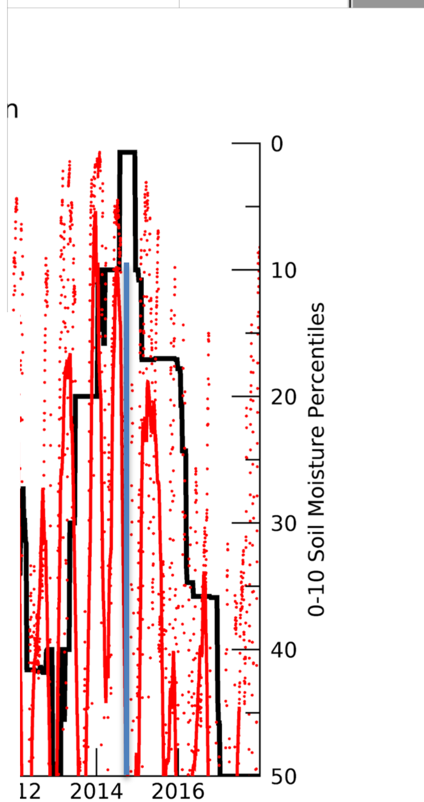

0
10
20
30
40
50
0-10 Soil Moisture Percentiles
12 2014 2016

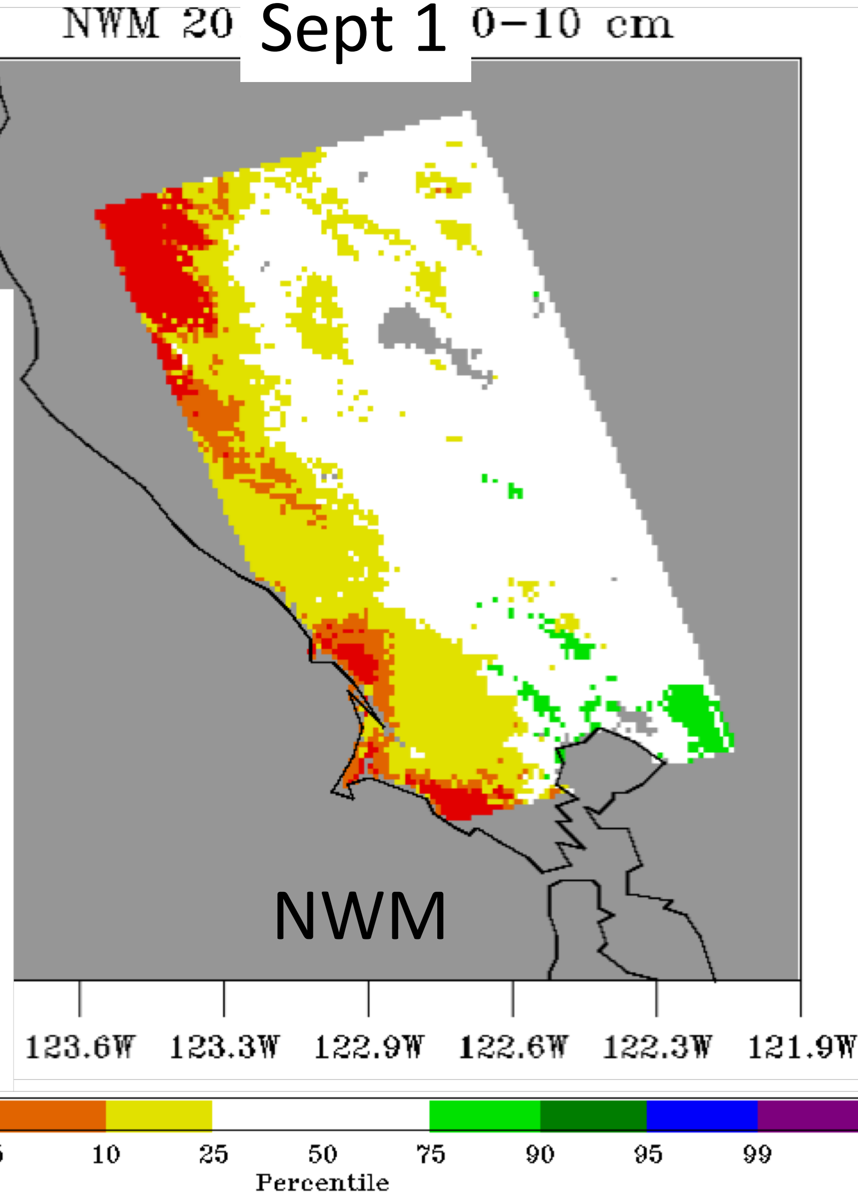

NWM 2014 Mar 10 10 cm
39.7N
39.3N
123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
NWM
1 5 10 25 50 75 90 95 99
Percentile

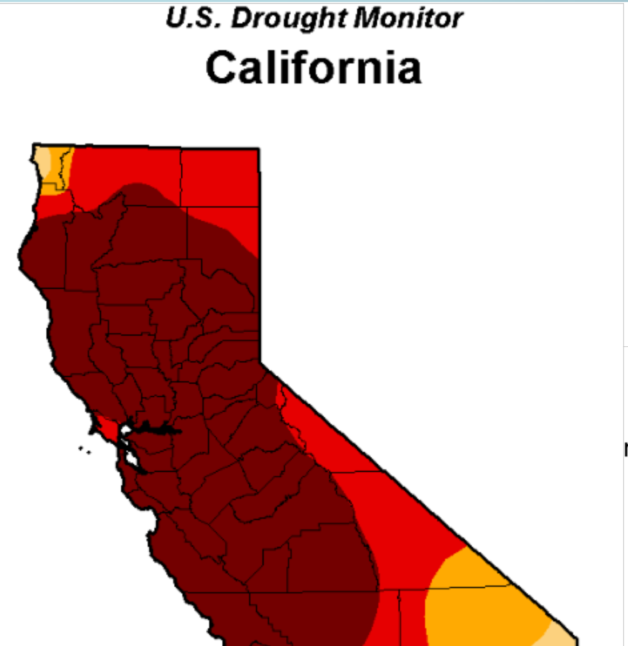

U.S. Drought Monitor
California
July 1
NWM 20 2 0–10 cm
39.7N
39.3N
123.6W
123.3W
122.9W
122.6W
122.3W
121.9W
NWM
1
5
10
25
50
75
90
95
99
Percentile
sin
0
10
20
30
40
50
0-10 Soil Moisture Percentiles
12
2014
2016
Noah 2014070112 0–10 cm
39.7N
39.3N
39.0N
38.6N
38.3N
37.9N
37.6N
123.9W
123.6W
123.3W
122.9W
122.6W
122.3W
121.9W
Noah

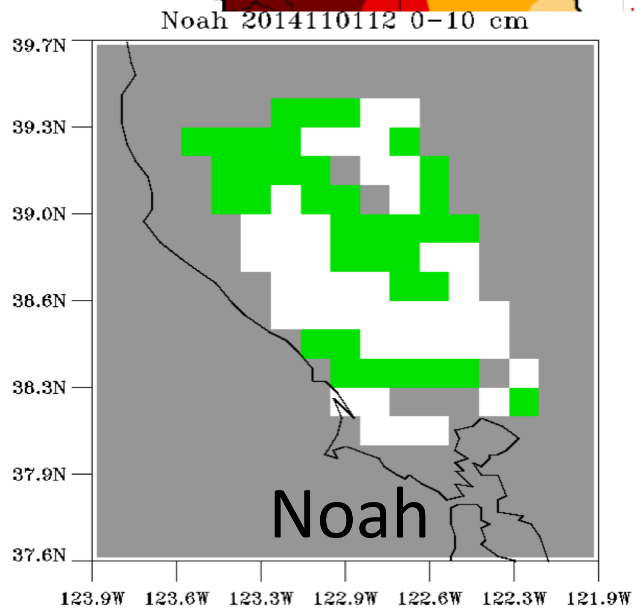

U.S. Drought Monitor
California

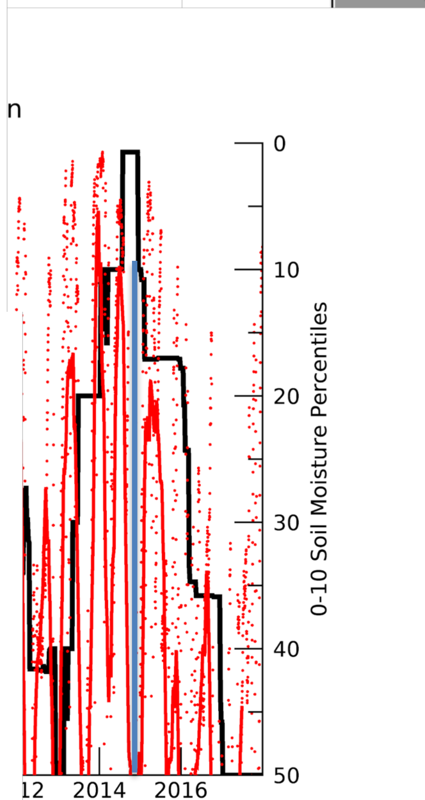

Noah 2014090112 0–10 cm
39.7N
39.3N
39.0N
38.6N
38.3N
37.9N
37.6N
123.9W 123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
Noah

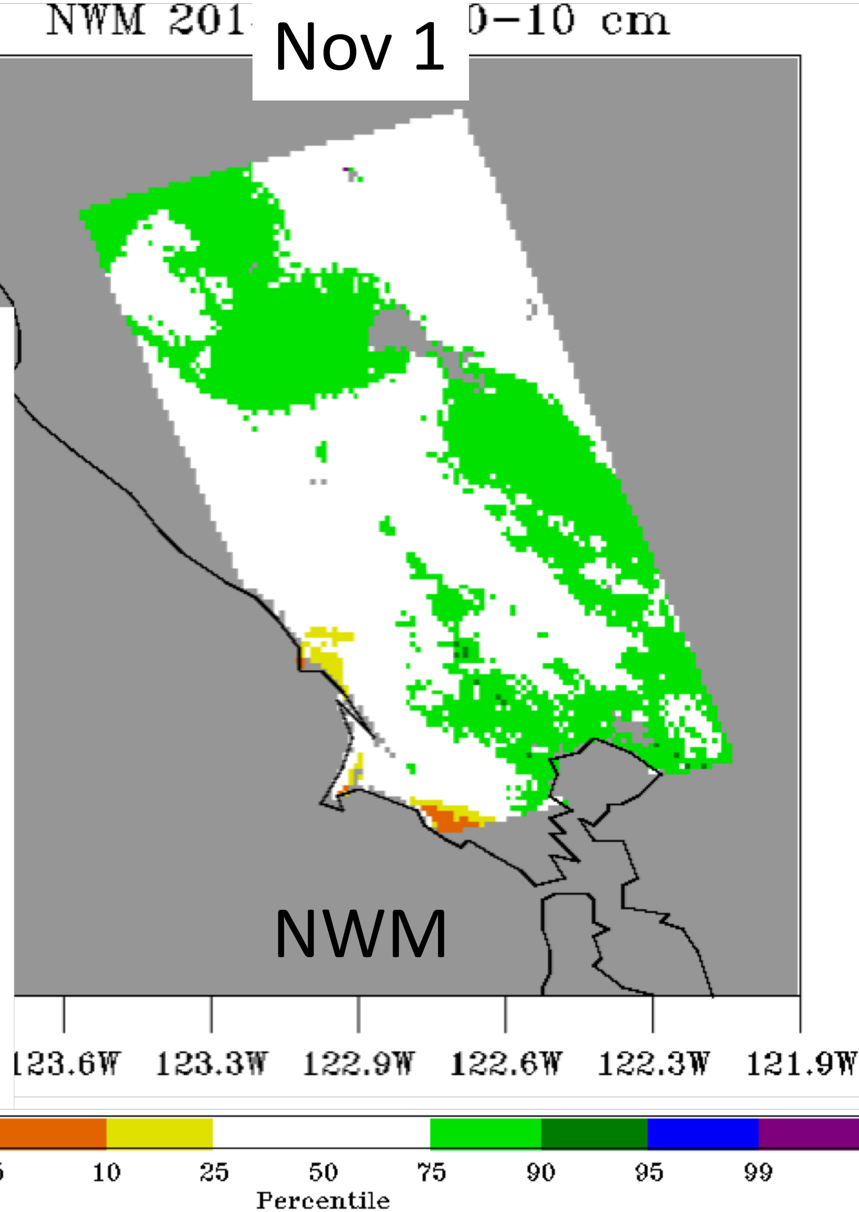

0
10
20
30
40
50
0-10 Soil Moisture Percentiles
12 2014 2016

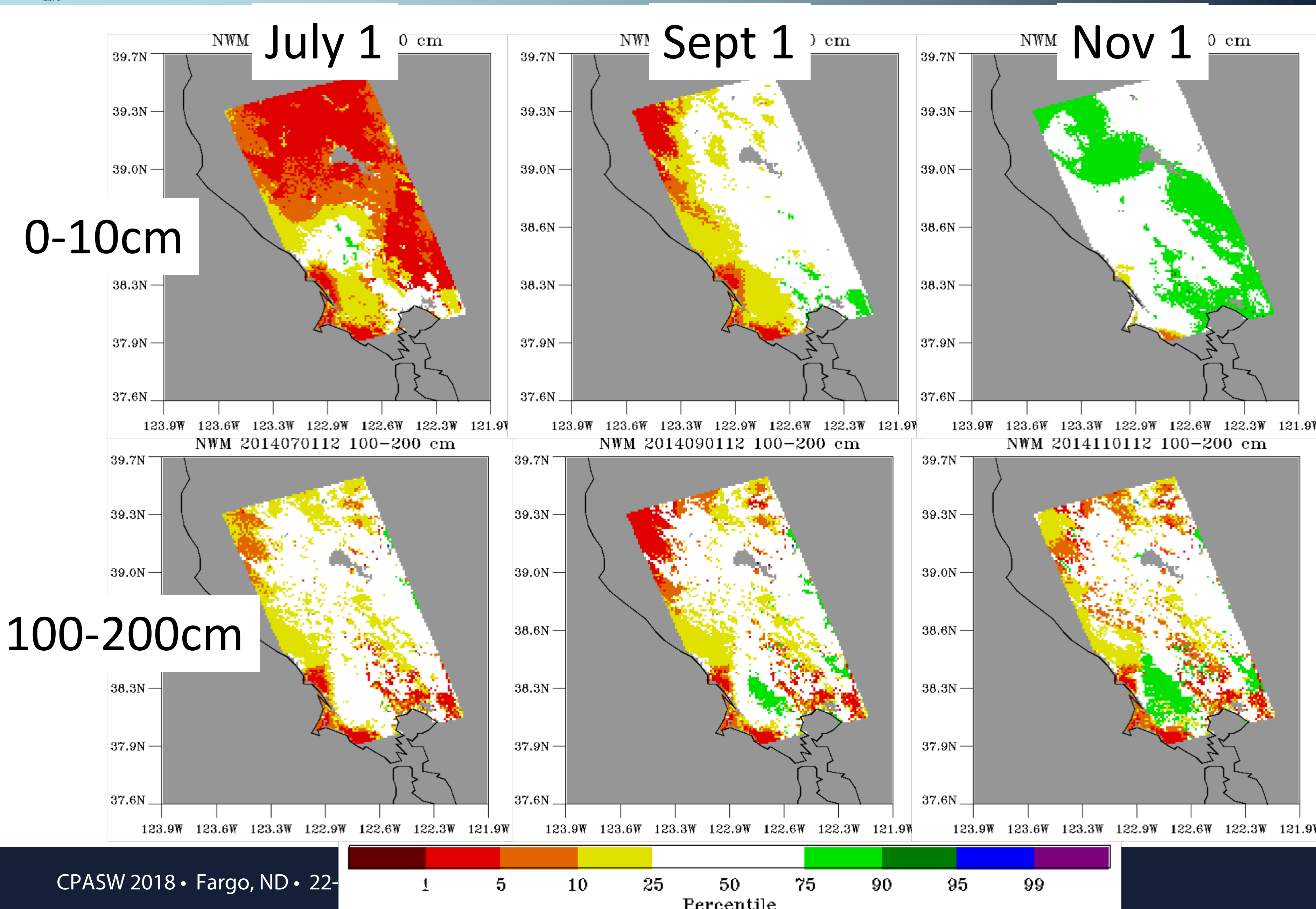

NWM 20 Sept 1 0–10 cm
39.7N
39.3N
123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
NWM
1 5 10 25 50 75 90 95 99
Percentile

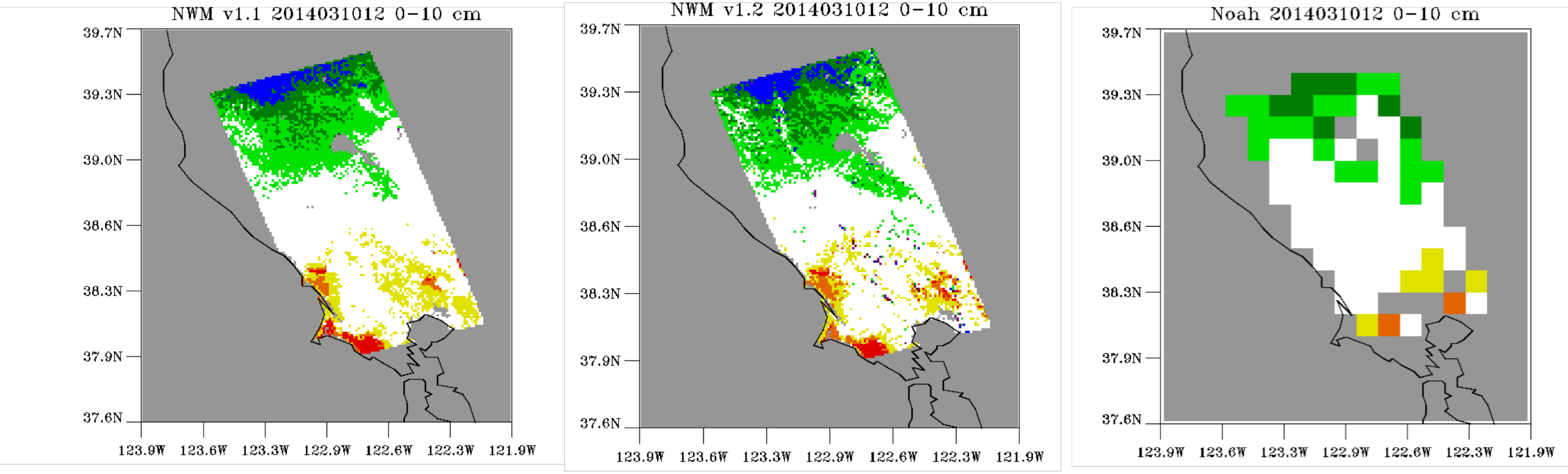

U.S. Drought Monitor
California


Noah 2014110112 0–10 cm
39.7N
39.3N
39.0N
38.6N
38.3N
37.9N
37.6N
123.9W 123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
Noah


0-10 Soil Moisture Percentiles
0
10
20
30
40
50
12 2014 2016

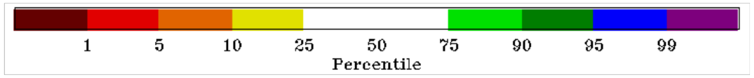

NWM 201 0–10 cm
Nov 1
39.7N
39.3N
123.6W 123.3W 122.9W 122.6W 122.3W 121.9W
NWM
1 5 10 25 50 75 90 95 99
Percentile

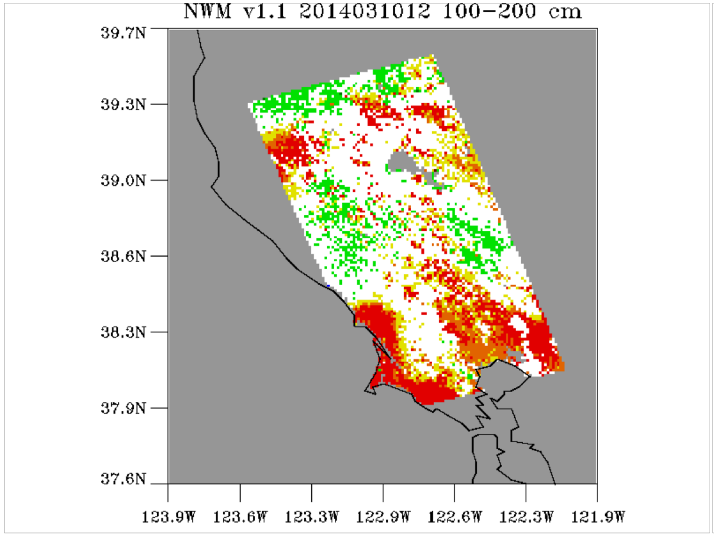

July 1
Sept 1
Nov 1
0-10cm
100-200cm
NWM 2014070112 100−200 cm
NWM 2014090112 100−200 cm
NWM 2014110112 100−200 cm
39.7N
39.3N
39.0N
38.6N
38.3N
37.9N
37.6N
123.9W
123.6W
123.3W
122.9W
122.6W
122.3W
121.9W
1
5
10
25
50
75
90
95
99
Percentile

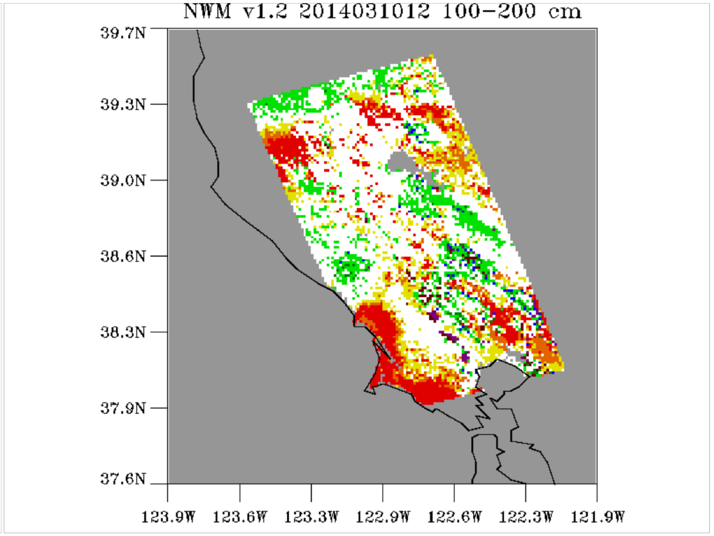


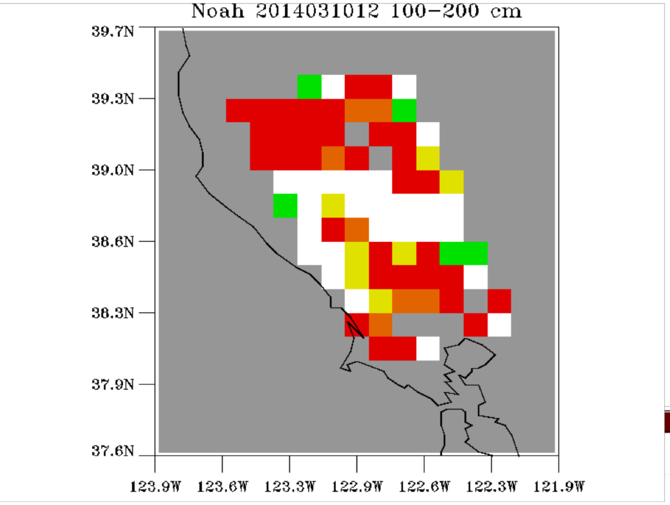
March 10, 2014

- 0-10 cm upper soil layer drying out from late Feb rainfall









March 10, 2014

- 100-200 cm lower soil layer becomes more wet
- NWM and Noah moistens more relative to climatology than CPC