Comparison of Modeled Snow Water Equivalents

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California Cooperative Snow Surveys Meeting
November 2014

Introduction

California Department of Water Resources (DWR), Snow Survey Section has been looking into improving and including additional resources to their forecasting procedure. Forecasting April-July full natural flow (A-J FNF) includes the use of statistical regression equations as a basis, but also additional resources and intuition.

DWR has invested into using USGS Precipitation-Runoff Modeling System (PRMS), which calculates snow water equivalent (SWE) as a parameter for runoff.

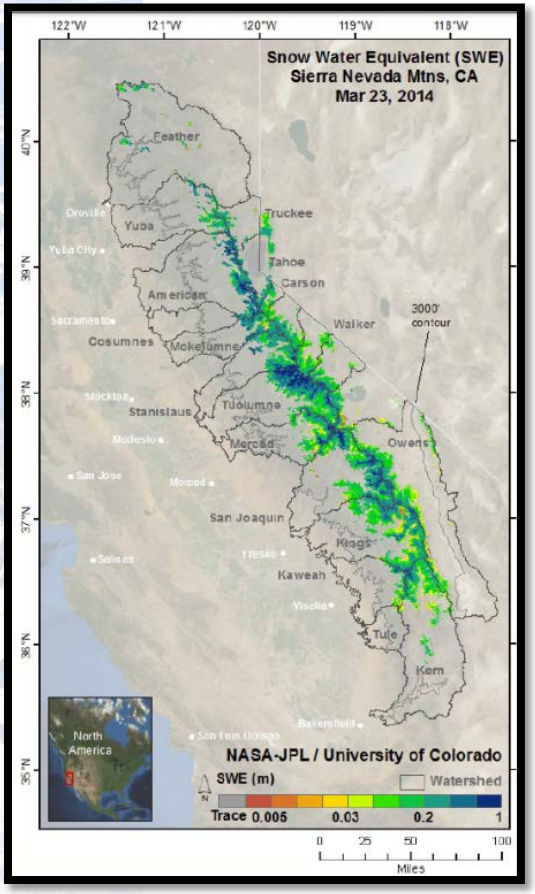
DWR would like to make use of newer tools in estimating SWE, but need a way to include it into current practices or determine its accuracy.

Few Issues Discussed

- Determining SWE in higher elevations → snow sensors are only within certain elevation bands
- Determining if SWE estimated products (gridded source, PRMS, etc.) are comparable to DWR regression equations
- If SWE estimated products are comparable to DWR regression equations, how to make use of it into current practices

Potential Application

JPL SWE Blended Product



Incorporating Gridded SWE Images into PRMS?

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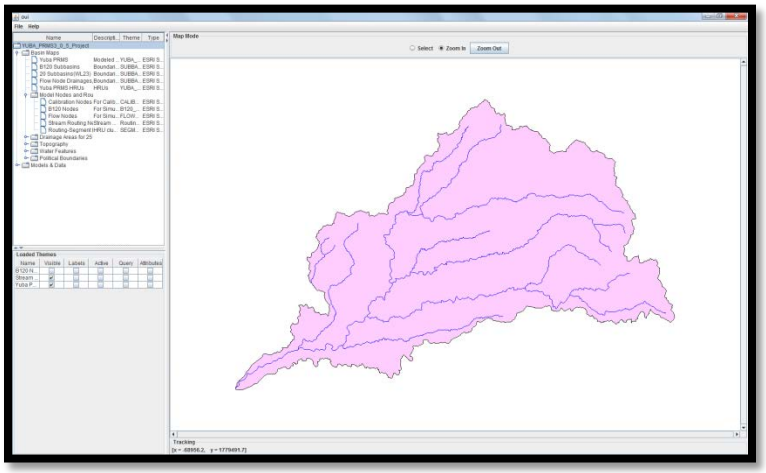
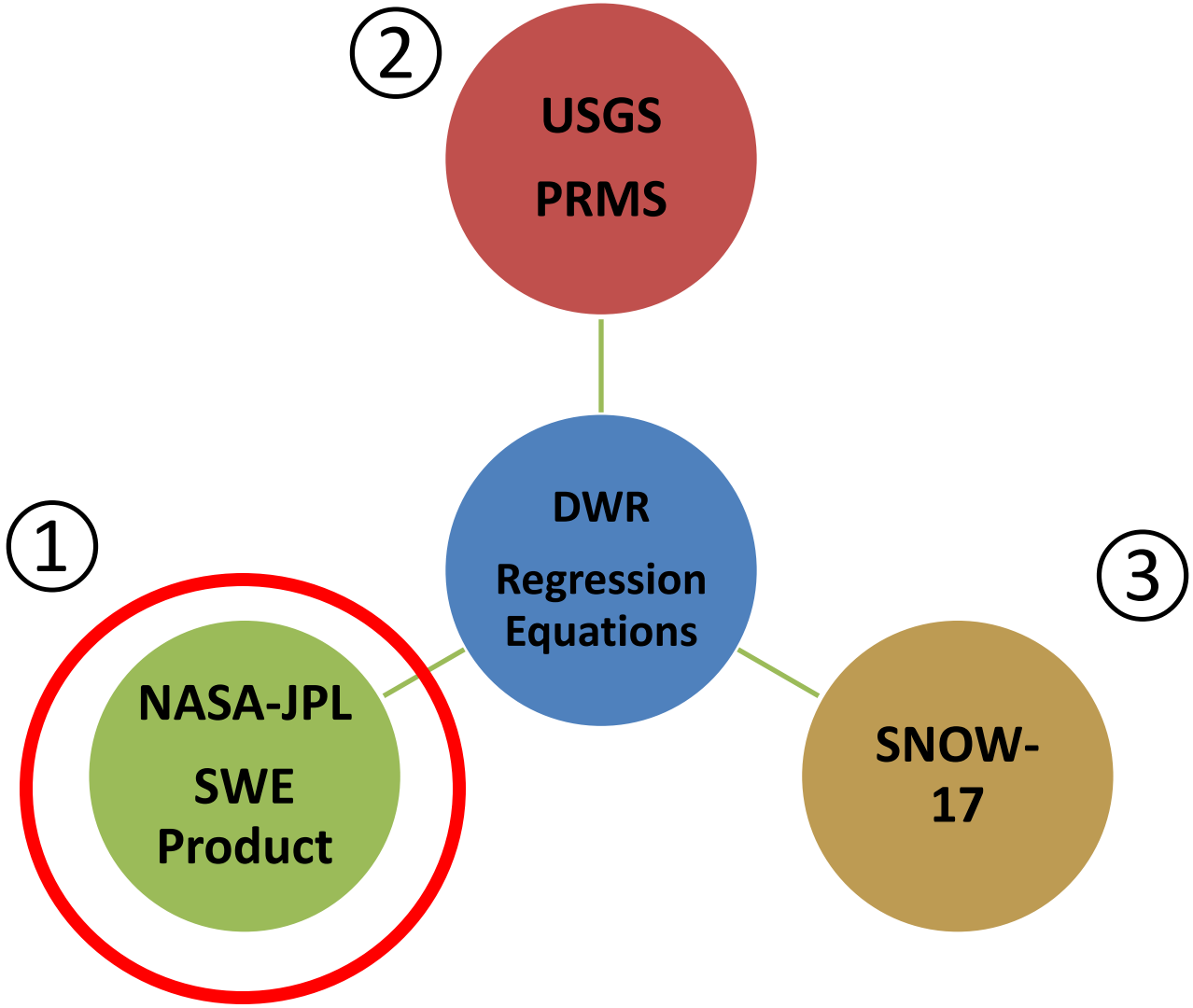
USGS PRMS



Purpose of Research: Comparison to DWR Regression Equations



Overview of:
DWR Regression Equations
&
JPL SWE Blended Product

DWR Regression Equations

Statistical Method Using Multiple Linear Regression

Primary Forecasting Tool → Multiple Linear Regression Analysis

- Specific for each watershed

Dependent Variable → April-July Cumulative Unimpaired Runoff

Independent Variables → Prior Year April-July Cumulative Unimpaired Runoff

→ October-March Cumulative Unimpaired Runoff

→ Snow Index (High Elevation)

→ Snow Index (Low Elevation)

→ October-March Precipitation Index

→ April-June Precipitation Index

DWR Sample Regression Equation

Kings River

April-July Unimpaired Runoff = 0.0464*(Prior Year Apr-Jul Unimpaired Runoff)

+ 8.3795*(High Snow Index)

+ 0.6661*(Low Snow Index)

+ 3.1807*(Oct-Mar Precipitation Index)

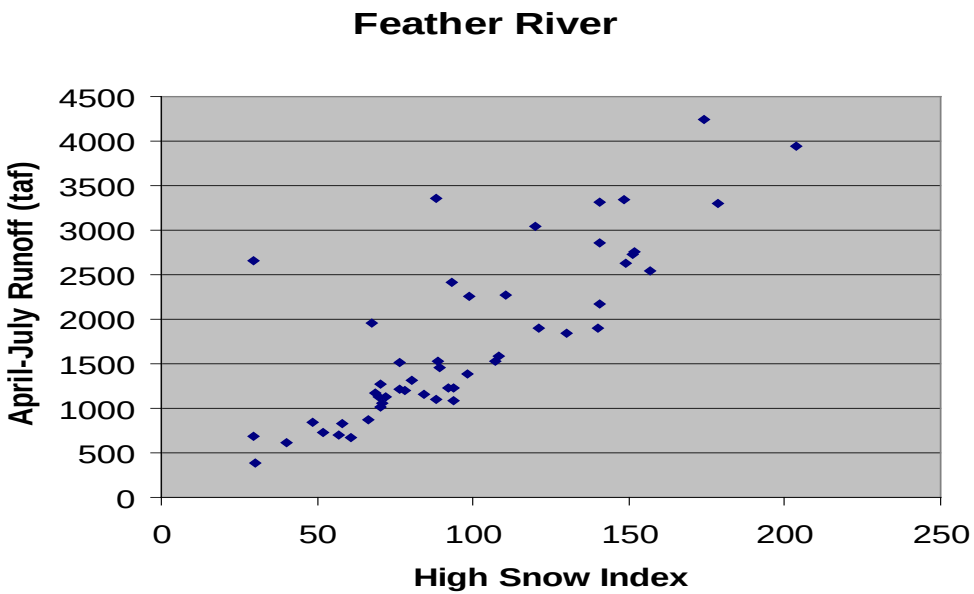
+ 2.5271*(Apr-Jun Precipitation Index)

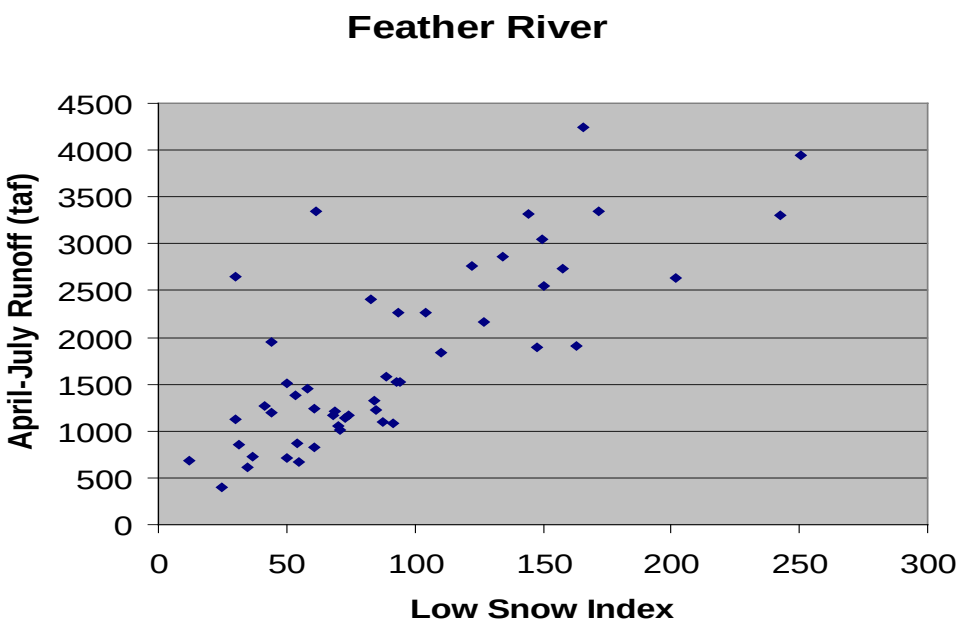
- 372

Each equation can be constructed with a unique set of independent variables

Some variables are excluded due to poor correlation (e.g. October-March runoff)

Snow Index and A-J FNF Correlation





Sample Snow Index Calculation

Feather River inflow to Lake Oroville

#	ID	Name	Basin	Dir	Elev	A 4/1avg	High Snowpack Pr.st	Ratio	Sched	Date	B raw WC	C int Pcp	adj WC	D % avg	est %
361	KTL	Kettle Rock	Feath	⇟	7300'	23.0	7	.7	_2345	03/24/09	22.8	0	22.8	99	
48	MDY	Mount Dyer	Feath	↑	7100'	25.5	6	1.0	_234_	03/30/09	26.7	0	26.7	105	
359	GRZ	Grizzly	Feath	⇟	6900'	30.3	7	1.1	_2345	03/30/09	24.4	0	24.4	81	
279	ERB	Eureka Bowl	Feath	↓	6800'	44.3	8	2.6	_2345	03/26/09	34.3	0	34.3	77	
280	RWL	Rowland Creek	Feath	→	6700'	17.8	7	.7	12345	03/25/09	10.8	0	10.8	61	
360	MHG	Mount Hough	Feath	⇟	6700'	29.5	7	1.1	12345	03/26/09	24.9	0	24.9	84	
75	CHU	Church Meadows	Feath	↓	6700'	32.1	8	1.9	12345	03/27/09	28.6	0	28.6	89	
74	YBP	Yuba Pass	Yuba	↘	6700'	30.9	8	.9	_2345	03/31/09	28.0	0	28.0	91	
45	SVR	Silver Lake Meado	Susan	↖	6450'	29.6	5	.9	45	04/01/09	22.0	0	22.0	74	
53	3LK	Three Lakes	Feath	←	6250'	39.9	7	1.5	_234_	03/31/09	32.6	0	32.6	82	
54	MLF	Mill Creek Flat	Feath	←	5900'	39.2	7	1.5	_234_	03/31/09	28.0	0	28.0	71	
49	LTT	Letterbox	Feath	←	5600'	49.9	7	1.9	_234_	03/31/09	40.7	0	40.7	82	
	Basin average:				6590'	32.7				03/28/09	27.0	0	27.0	83.0	83.0
	Average of reporting courses:				6590'	32.7			Feb 1	Mar 1	Apr 1		Future Increment:		0.0
12	courses					Hist Median Increm:			30	8	0		Apr 1 Index:		83.0

$$D = (B + C) / A$$

JPL SWE Products

<u>What is the JPL SWE product?</u>

Spatial distributed estimates of daily melt-season SWE over Sierra Nevada for March to August from 2000-2012 by the following methods:

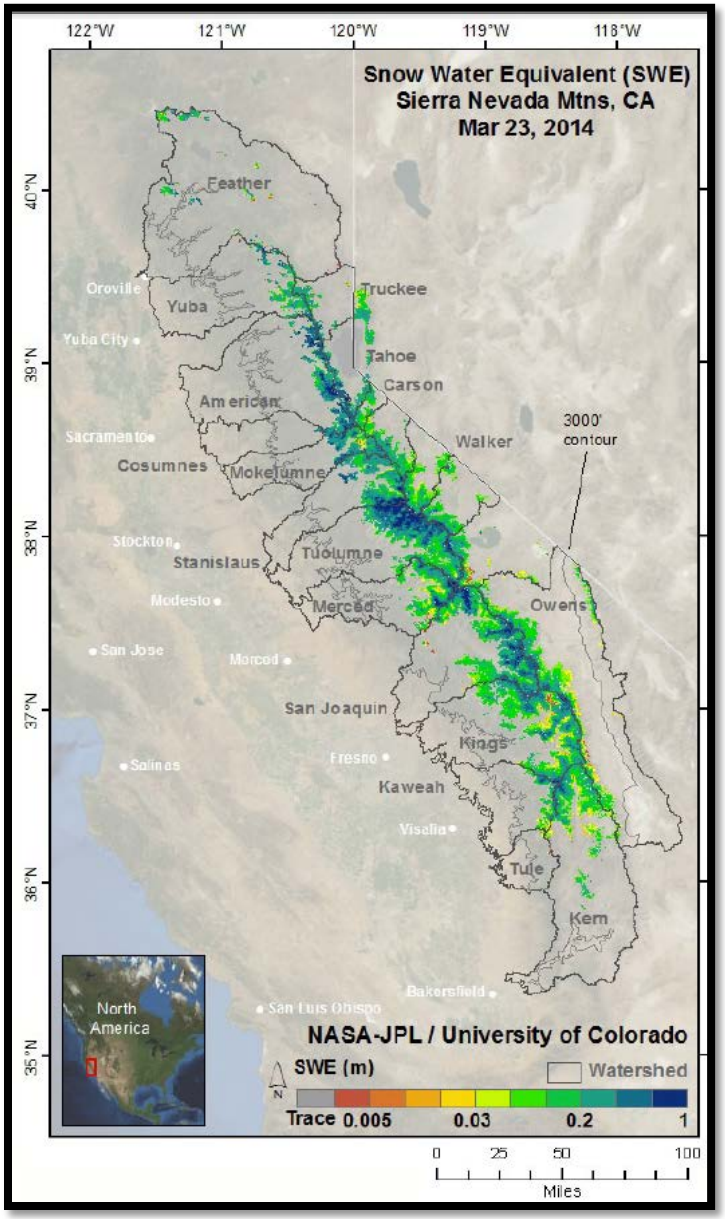
①Reconstruction
②Blended

Reconstruction Method:

- Combines snow cover area images from satellite images (i.e. MODSCAG) with a spatially distributed snowmelt model

Blended Method:

- Reconstruction product combined with snow sensor readings



Overview JPL SWE Products

1. Snow-Covered Area (SCA):
   - Fractional SCA (portion of 500mx500m grid cell covered with snow) → determined from MODSCAG images

2. Several Model Forcings:
   - Used to determine potential melt for each pixel, then the actual melt can be determined with SCA

3. Reconstructed SWE Product:
   - Determined from 1 and 2

4. Blended SWE Product:
   - Determined from 3 and a distributed residual

JPL Reconstructed SWE Product

Potential snowmelt at each pixel determined with the energy balance:

$$M_p \rho L = S \downarrow (1 - \alpha) + LW \downarrow + LW \uparrow + SH + LH$$

M_p = Potential melt

ρ = Density of liquid melt

L = Latent heat exchange

S = Subcanopy insolation

α = Snow albedo

LW = Longwave radiation

SH = Sensible heat exchange

LH = Latent heat exchange

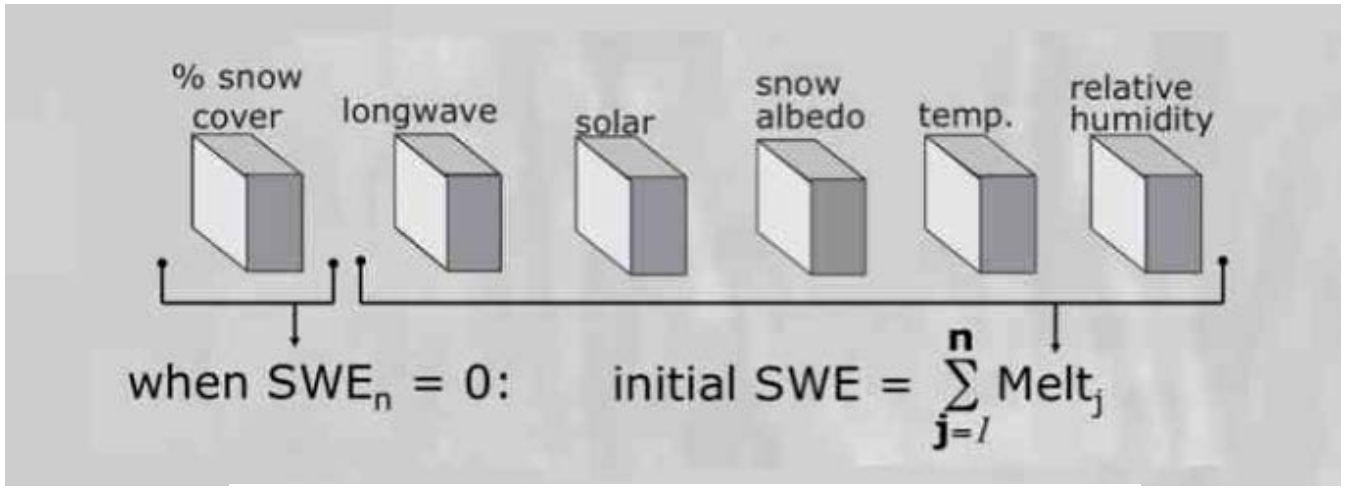
JPL Reconstruction SWE Product

Reconstructs daily gridded estimates of SWE by the following:

$$M = M_p \times f_{SCA}$$

$$SWE_n = SWE_0 - \sum_{j=1}^{n} M_j$$

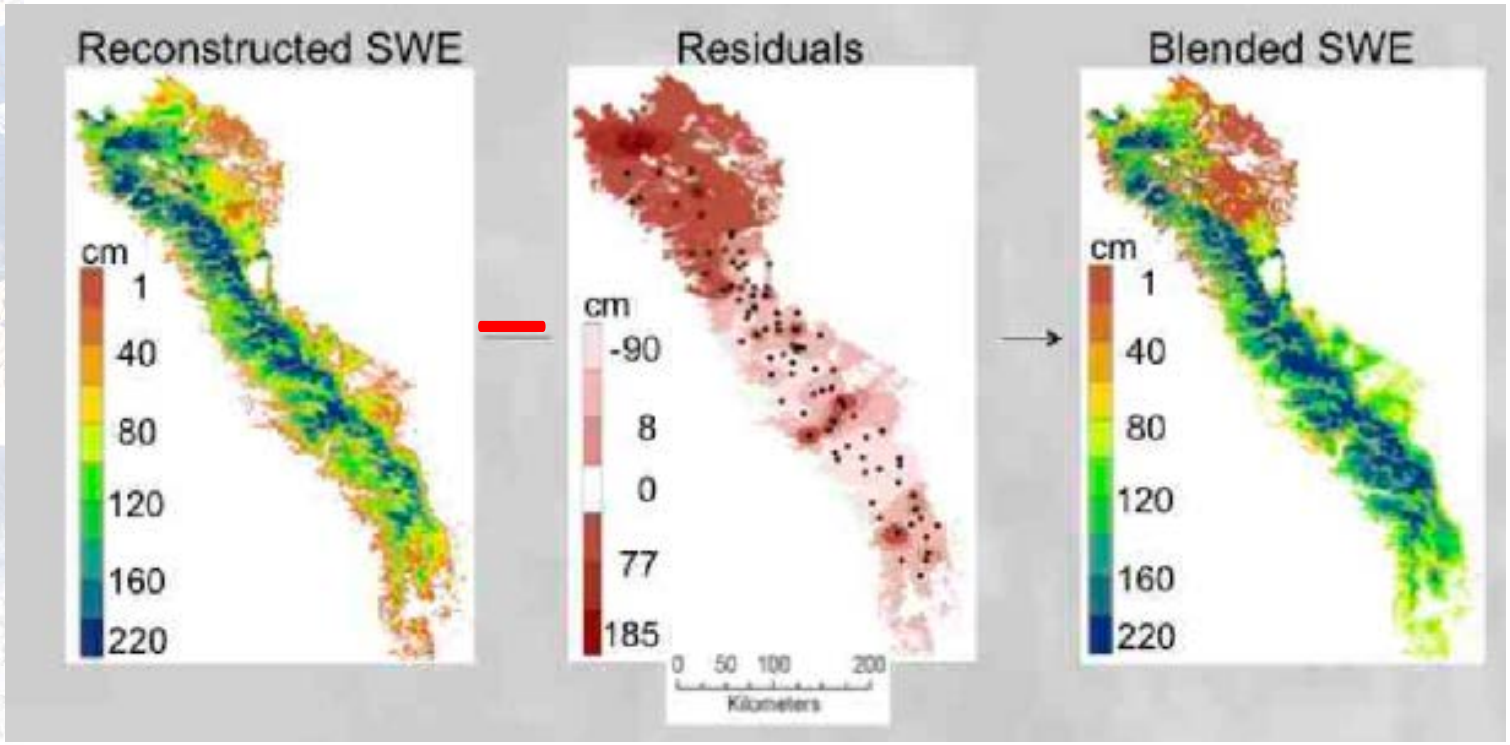
SWE_0 (i.e. peak SWE), can be determined by the cumulative melt flux when there is no more snow in a pixel (i.e. $SWE_n = 0$):



$$SWE_0 = \sum_{j=1}^{n} M_j, \text{ when } SWE_n = 0$$

JPL Blended SWE Product

1. Difference between Reconstructed SWE and snow sensor SWE readings (at each snow sensor location) determined
2. Difference distributed to all pixels → using inverse of squared distance as distribution weights → **Distributed Residuals**
3. For each pixel: Reconstructed SWE – Distributed Residual = **Blended SWE**



Overview of Comparison: JPL Blended Product and DWR Regression Equations

Developing a Comparison Method

JPL
Blended Product

Estimates SWE as a gridded image

SWE

DWR
Snow Index

Uses SWE as a input to calculate a Snow Index

Comparison on Elevation Band Average SWE

① Determine Average SWE Based on Elevation Bands

Watershed	Elevation	3/16/14 % Avg to Date	3/23/14 SWE (in)	3/16/14 SWE (in)	3/16 thru 3/23 Change SWE (in)	Area Sq Mi
FEATHER	3000-4000'	0.00	0.00	0.00	0.00	286.2
	4000-5000'	0.00	0.00	0.00	0.00	735.8
	5000-6000'	0.35	0.05	0.11	-0.07	1305.1
	6000-7000'	5.16	0.91	1.47	-0.57	871.3
	7000-8000'	12.15	3.07	3.99	-0.92	124.6
	8000-9000'	17.98	5.43	6.14	-0.71	5.2

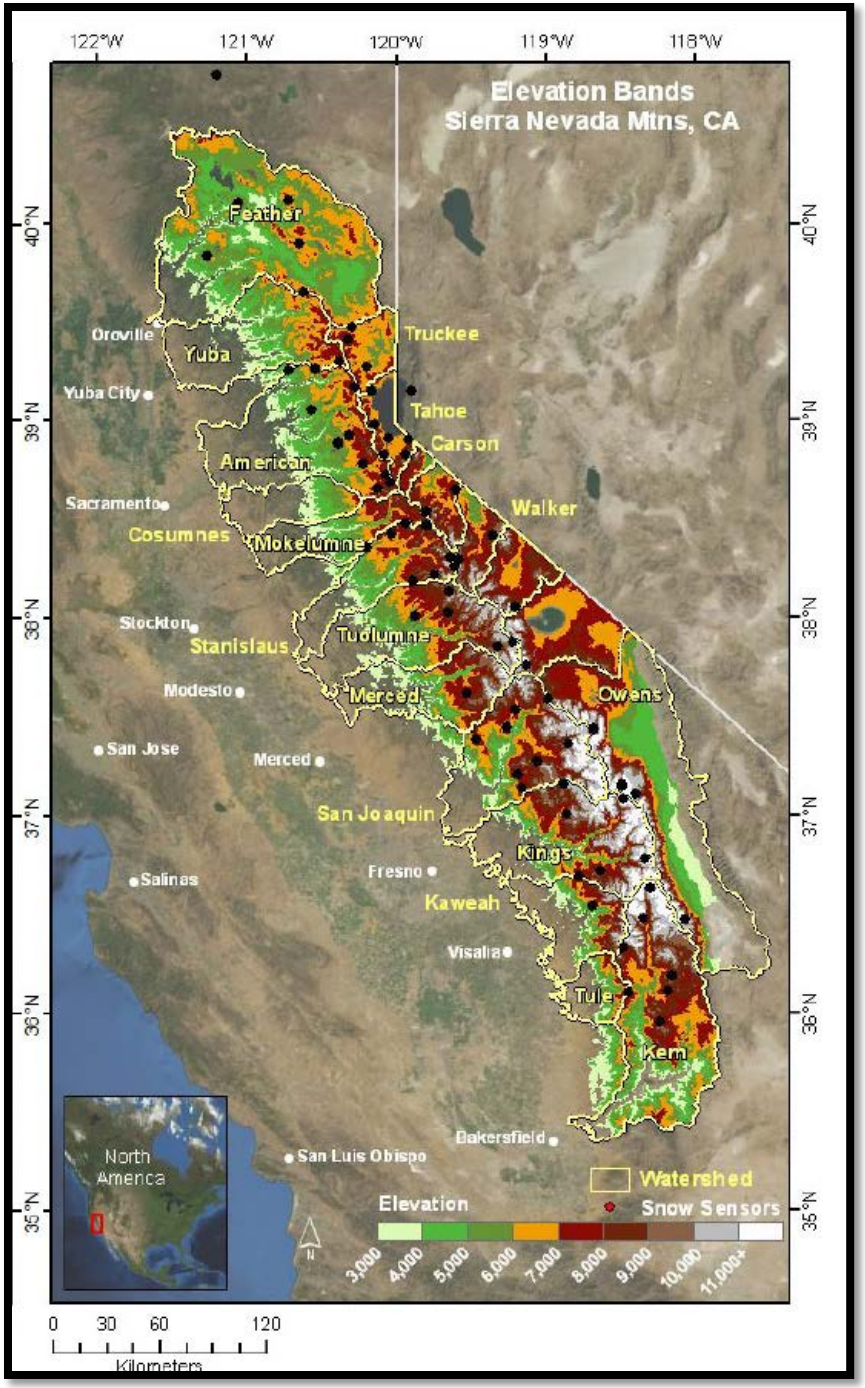
② Interpolate Average SWE In-between Elevation Bands

- In order to compare with sensor station readings used to develop DWR snow index value

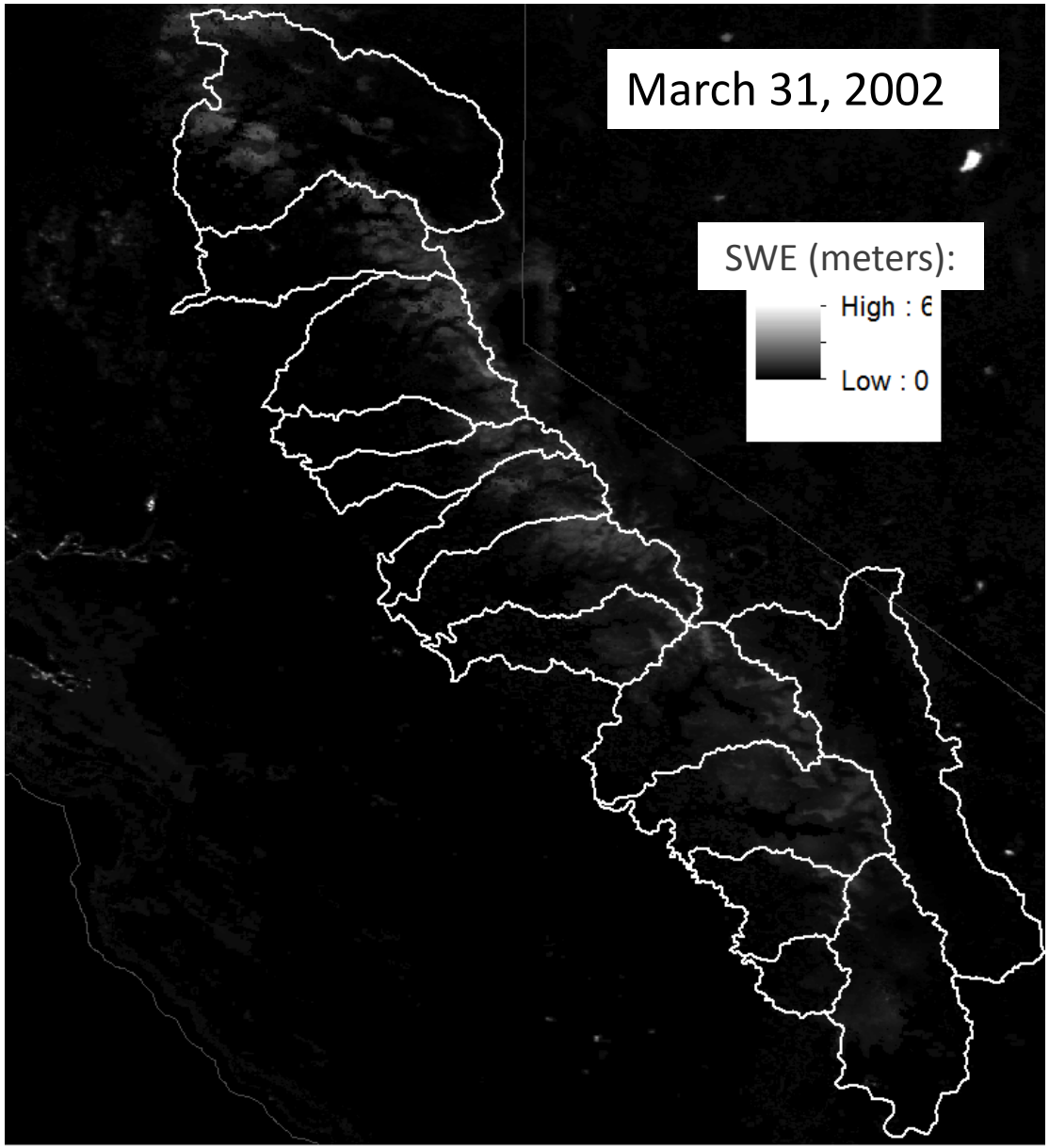
Elevation Bands

Average SWE determined with the following elevation bands:

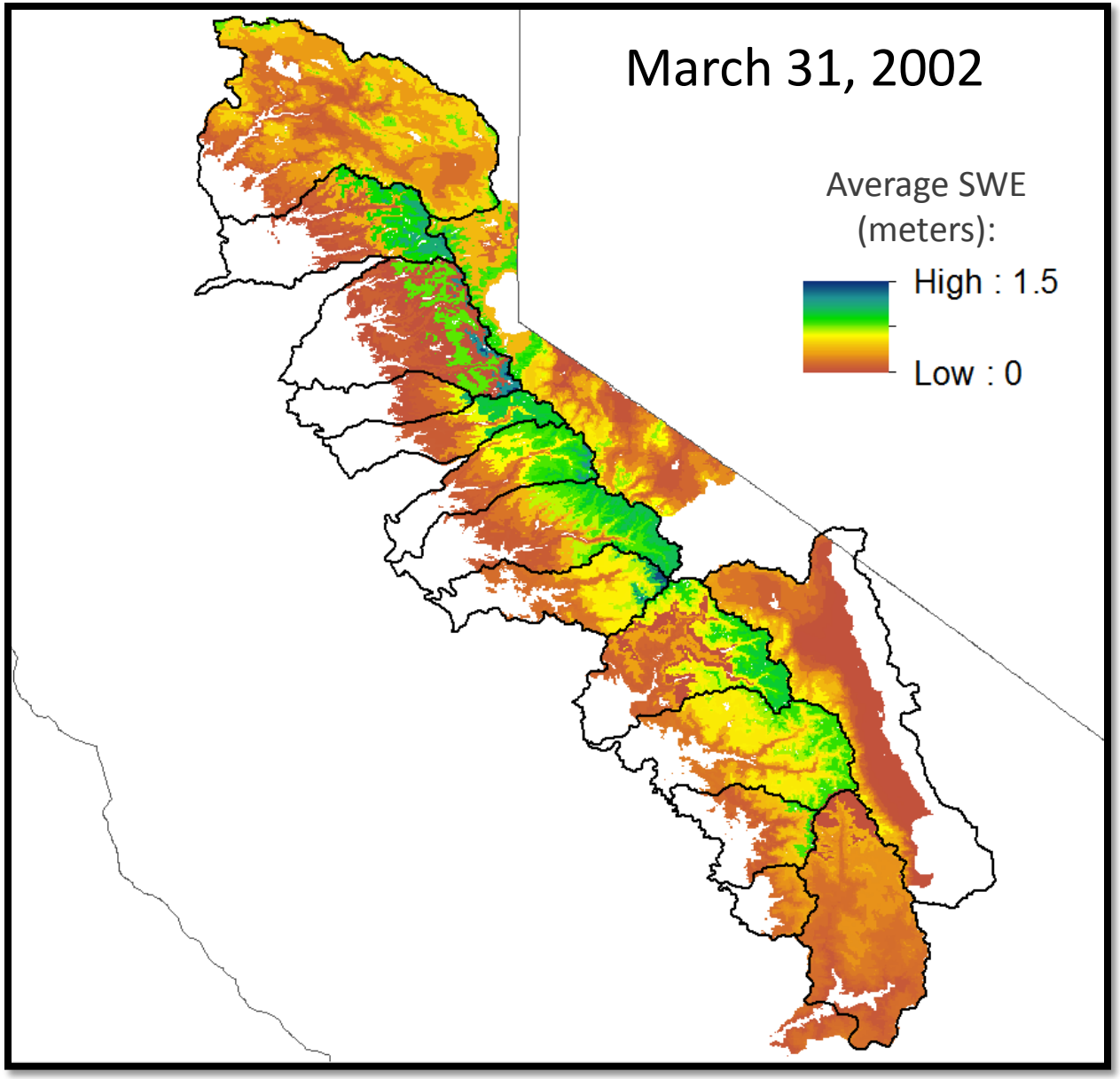
3,000 – 4,000 feet
4,000 – 5,000 feet
5,000 – 6,000 feet
6,000 – 7,000 feet
7,000 – 8,000 feet
8,000 – 9,000 feet



JPL Blended SWE Image



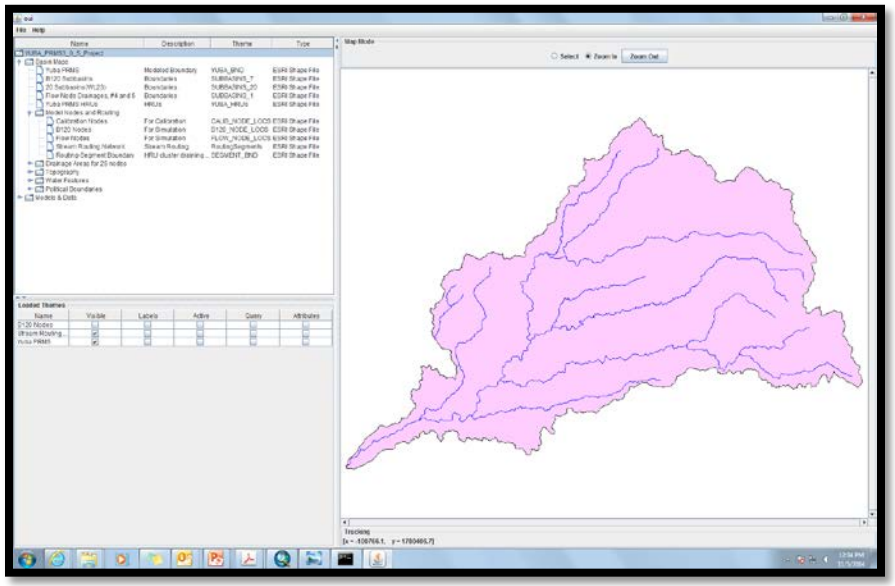
Elevation Band Average SWE



Current and Future Work

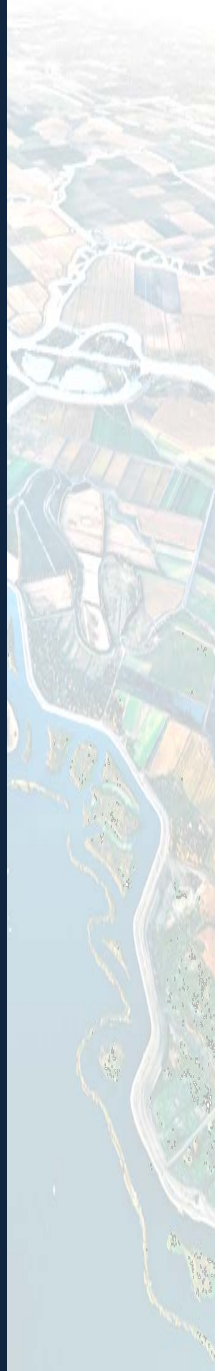
- Processing through roughly 840 JPL Blended SWE images for Feather and Yuba:
  - Cloud-free satellite image dates
  - March-August for the years 2000-2012
  - To obtain tables for elevation banded average SWE

- Same process but with using PRMS and SNOW-17:
  - Determine average SWE by elevation bands to obtain tables to compare



Acknowledgments

- Noah Molotch, Jet Propulsion Laboratory
- Leanne Lestak, University of Colorado Boulder
- David Rizzardo, Department of Water Resources
- Steve Nemeth, Department of Water Resources
- John King, Department of Water Resources
- Mike Anderson, Department of Water Resources
- Levent M. Kavvas, University of California, Davis



Questions ?