

Pillow Talk: Flow Forecasting for the Cowichan River with Snow Pillow Technology



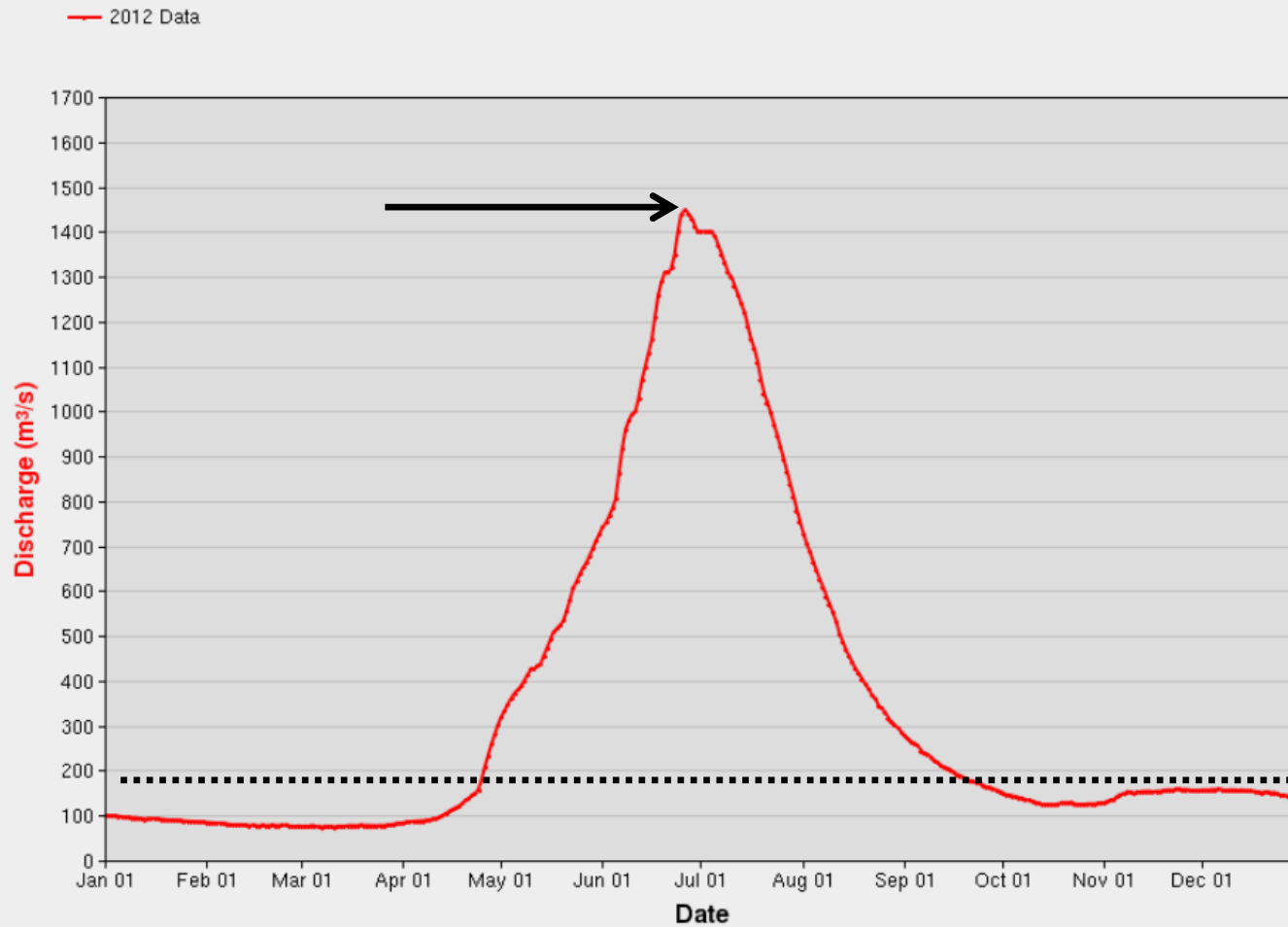
Cowichan Water Board-VIU Speaker Series
Dave Campbell, MSc, PGeo
Head, River Forecast Centre
April 28, 2016

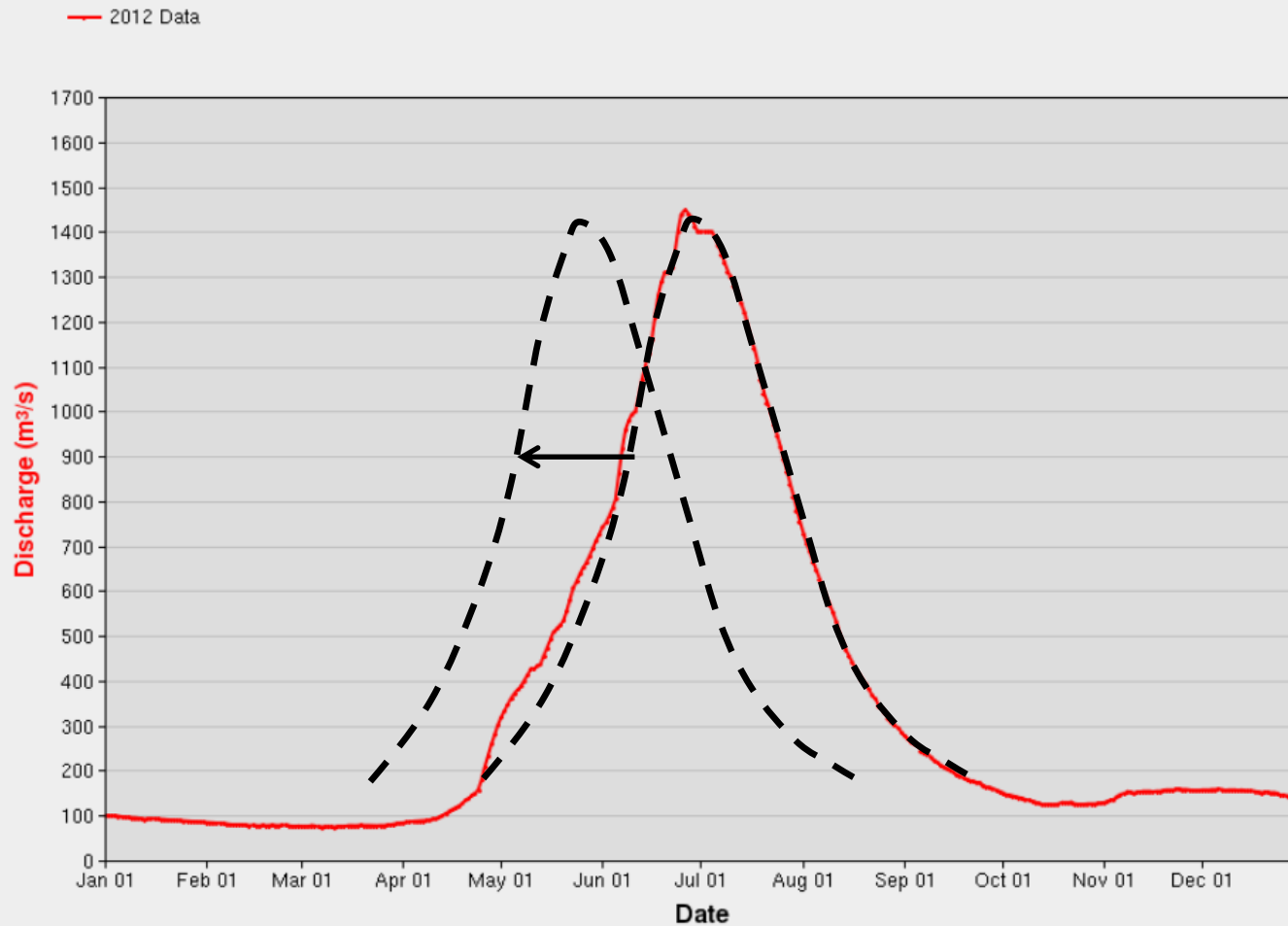
Overview

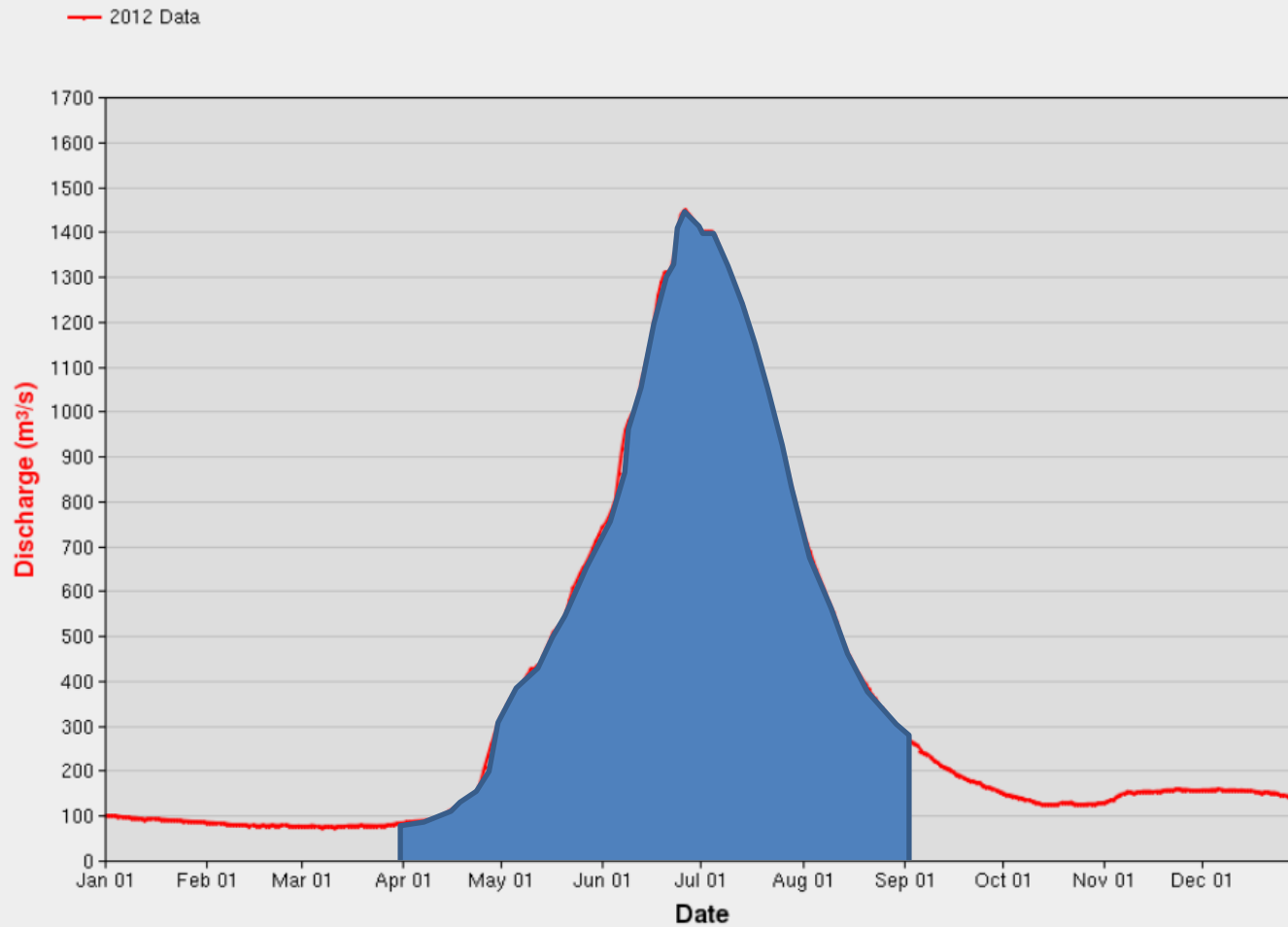
- River Hydrology
- Snow Measurement and Analysis
- Cowichan River and Heather Mountain Snow Pillow
- Recent Case Studies
- Future

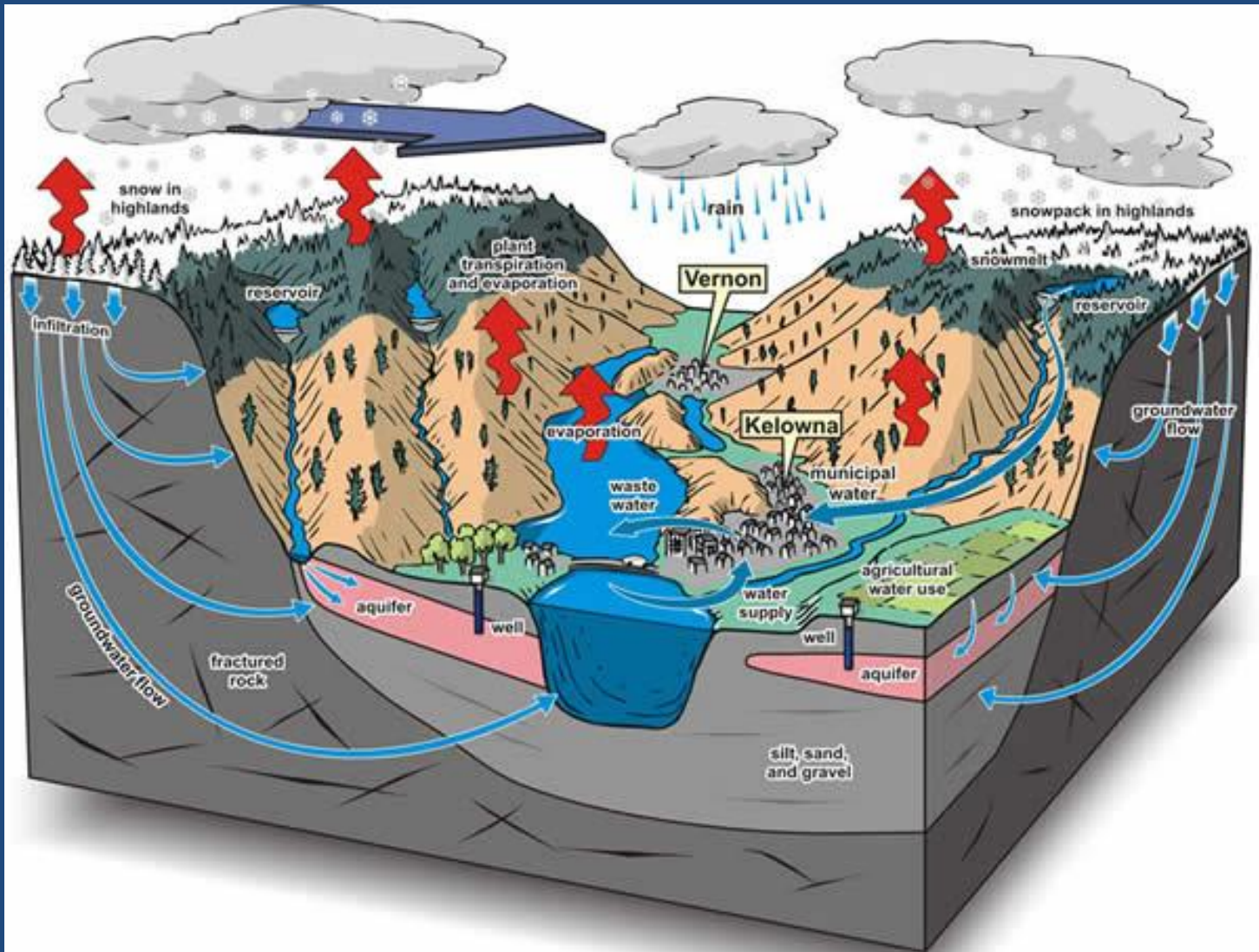
- Public Safety & Emergency Management
- Water Supply
 - Community water
 - Recreation
 - Agriculture
 - Industry
 - Water Licencing
- Aquatic Habitat
- Planning







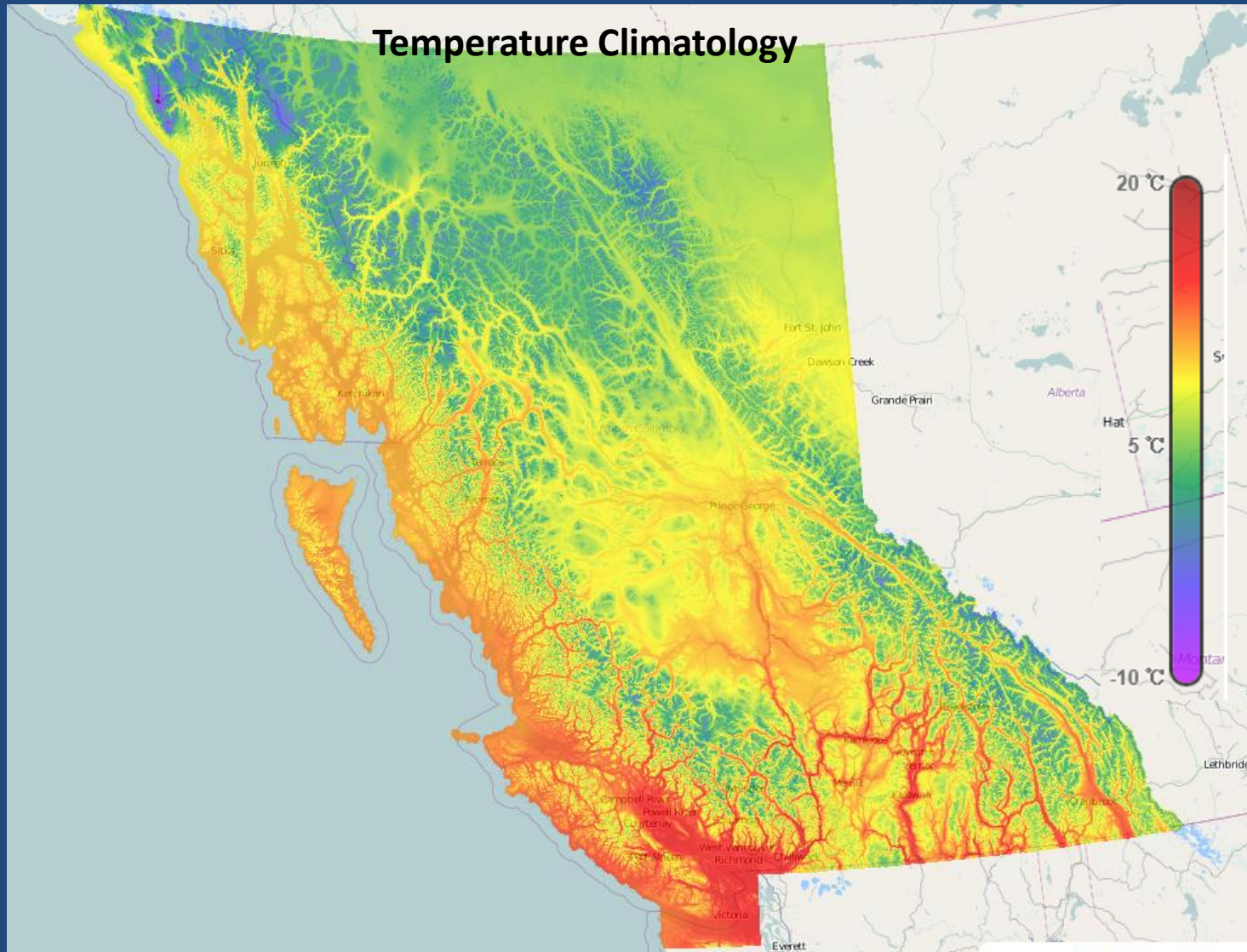


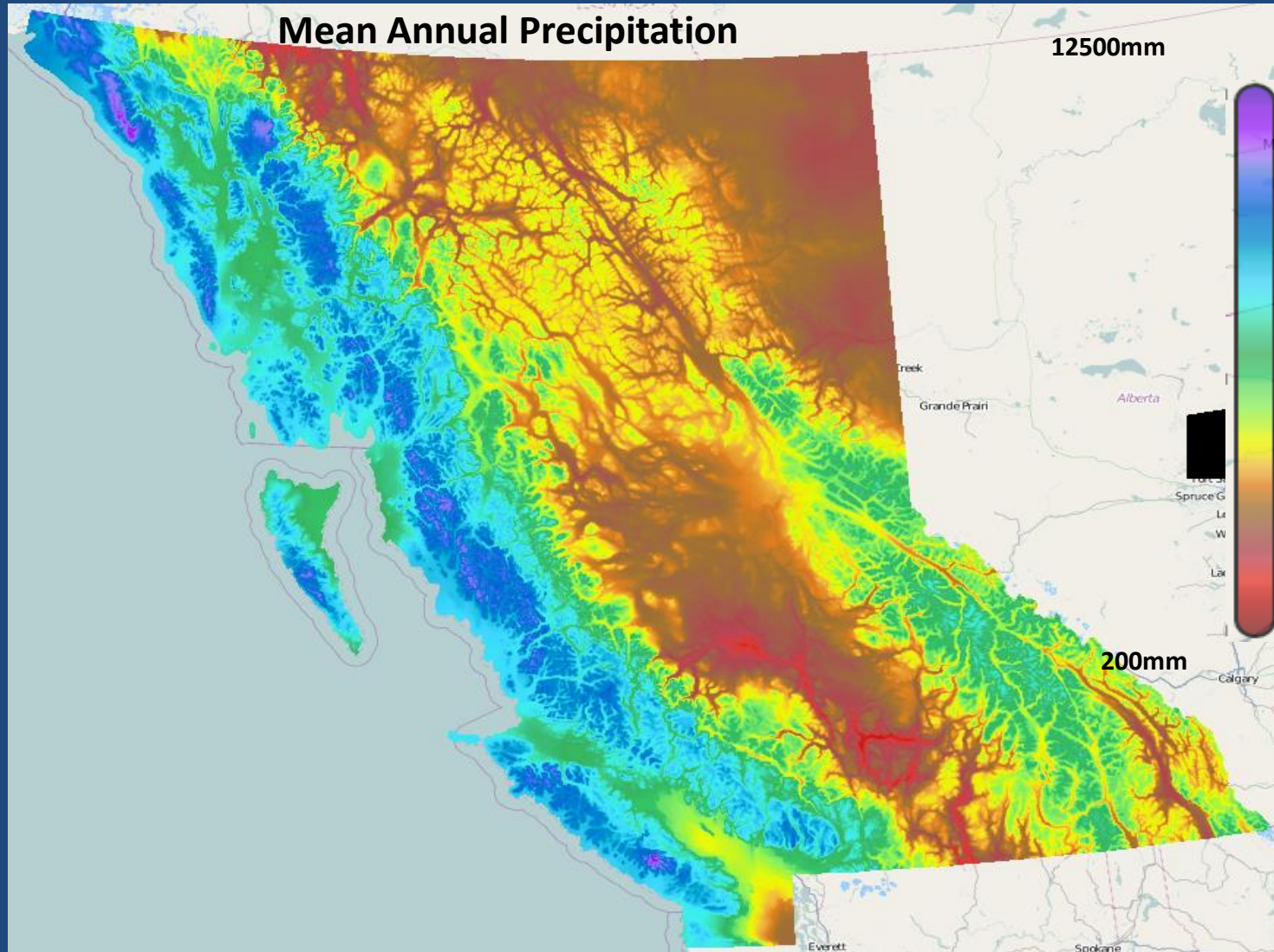


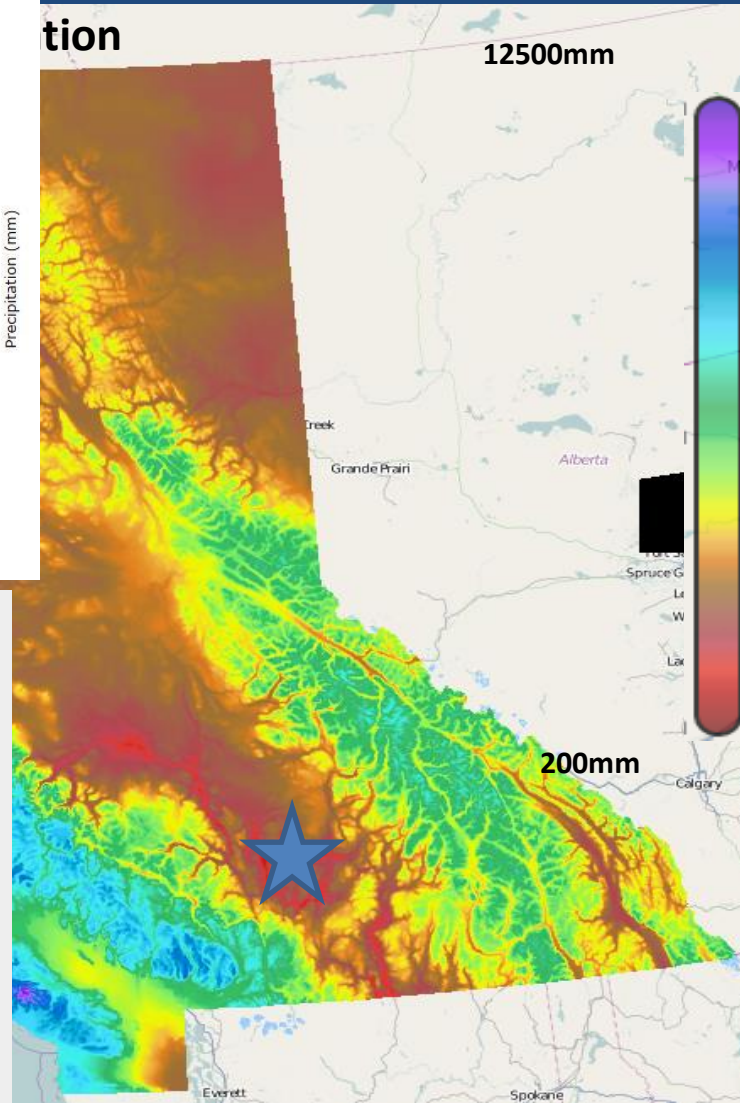
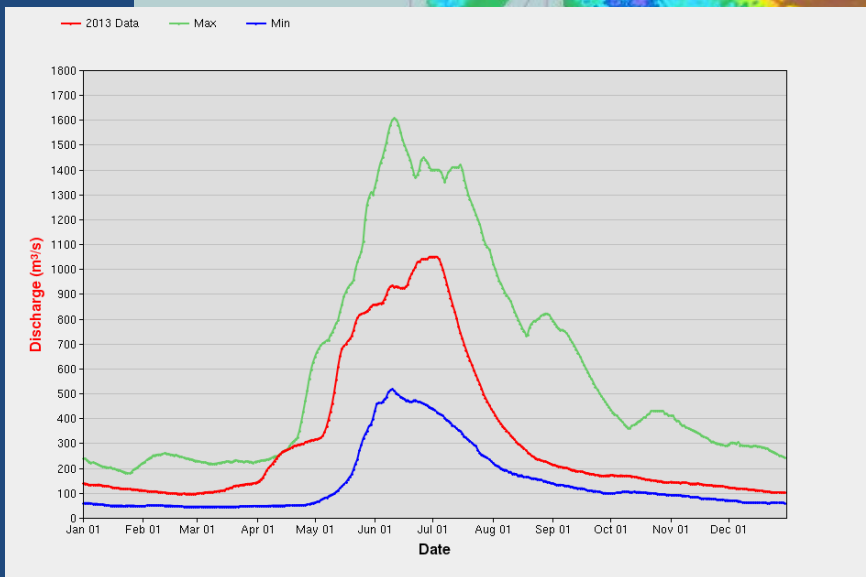
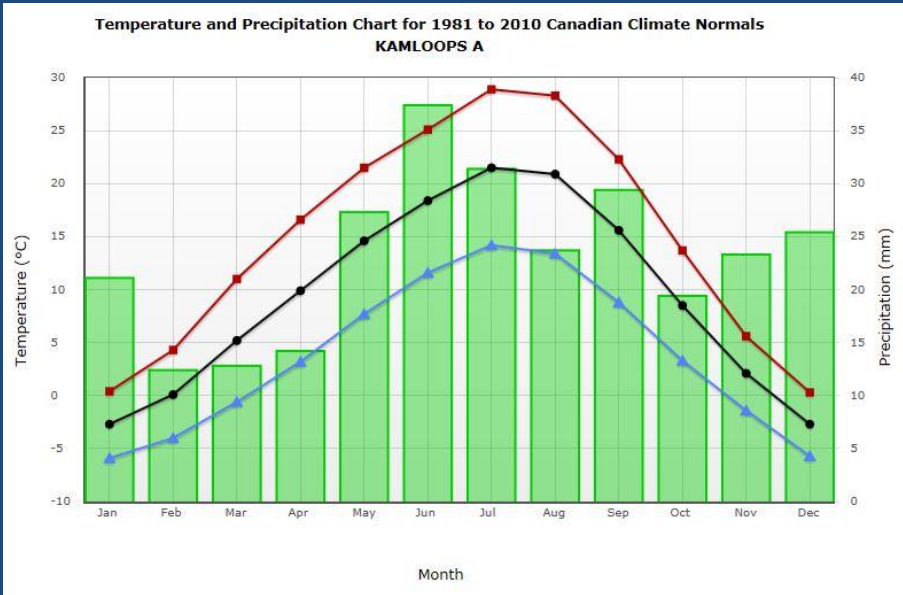
Source: Okanagan Water Board

British Columbia

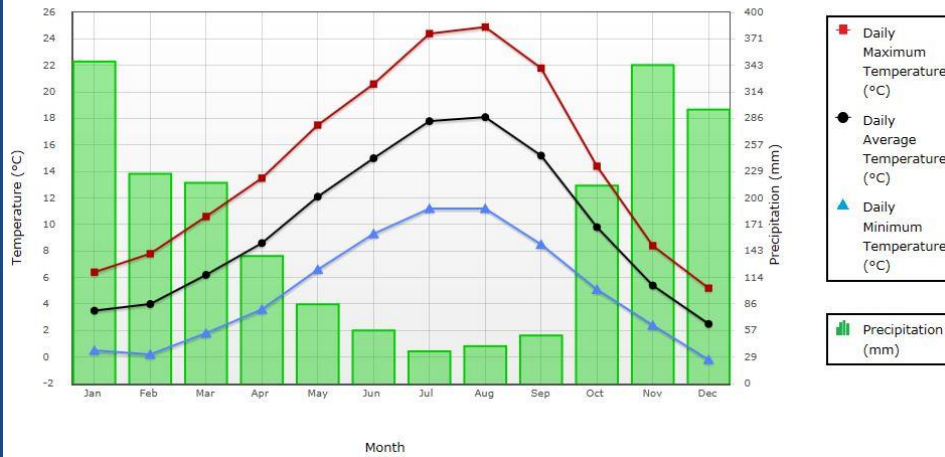






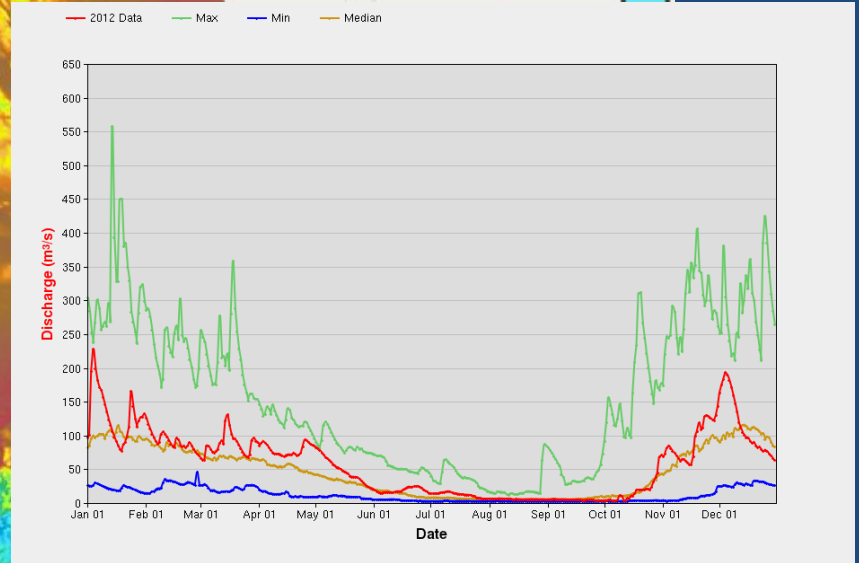


Temperature and Precipitation Chart for 1981 to 2010 Canadian Climate Normals
LAKE COWICHAN



on

12500mm



Source: ClimateBC

DATA!

- *"Accurate information on the condition and trends of a country's water is required as a basis for economic and social development, and for maintenance of environmental quality through a proper perception of the physical processes controlling the hydrological cycle in time and space"*
--WMO/UNESCO Report on Water Resources Assessment, p. 16.



Hydrometric Monitoring

- Began in the early 1900`s
 - Originally agriculture focused, later water supply and hydro
- Water Survey of Canada
 - Active monitoring and data archiving

DEPARTMENT OF THE INTERIOR—DOMINION WATER POWER BRANCH, OTTAWA
OBSERVATIONS OF RIVER HEIGHT.
Coldwater R

Month	Day	WATER HEIGHT OF GAUGE				Mean	REMARKS ON CHANGES OF RIVER HEIGHT
		MORNING		AFTERNOON			
		Time	Height	Time	Height		
<i>April 1920</i>	<i>4</i>	<i>9:25</i>	<i>1.9</i>				
	<i>5</i>	<i>8:39</i>	<i>1.8</i>	<i>7:35</i>	<i>1.8</i>		
	<i>6</i>	<i>8:36</i>	<i>1.8</i>	<i>4:37</i>	<i>1.8</i>		
	<i>7</i>	<i>8:41</i>	<i>1.7</i>	<i>4:40</i>	<i>1.7</i>		
	<i>8</i>	<i>8:48</i>	<i>1.7</i>	<i>4:30</i>	<i>1.5</i>		
	<i>9</i>	<i>8:32</i>	<i>1.8</i>	<i>4:43</i>	<i>1.5</i>		
	<i>10</i>	<i>8:39</i>	<i>1.8</i>	<i>4:35</i>	<i>1.8</i>		

Under the head of remarks, give any facts on rain, snow, change of weather, and other occurrences liable to affect the height of the river. In floods note the rate at which the water rises in one or more hours, also extreme height and time of day. If river is dry, state this fact, or note whether the water is standing in pools.
I certify that the above observations were actually made by me and are correct.

Examined by (Sign.) *P. Antonick*, Observer





Government
of Canada

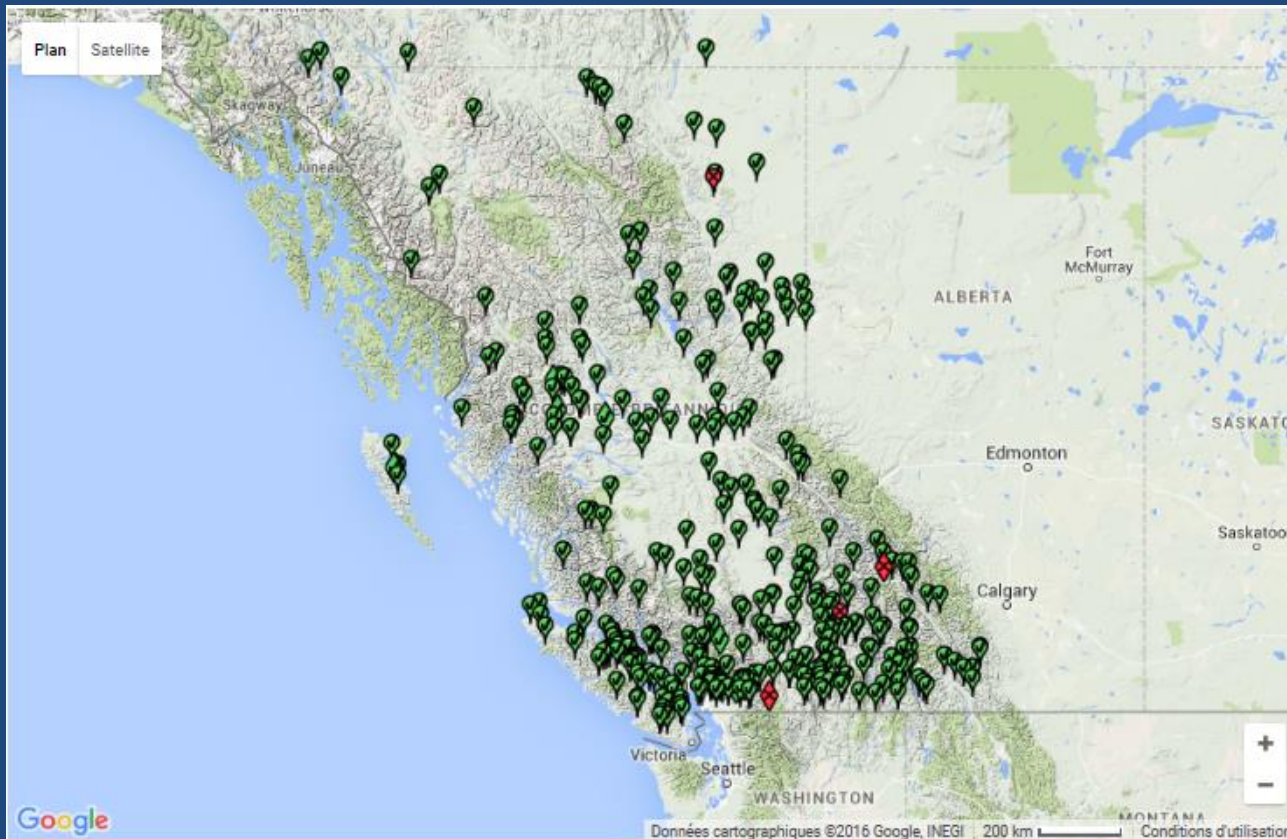
Gouvernement
du Canada

Canada.ca | Services | Departments | Français

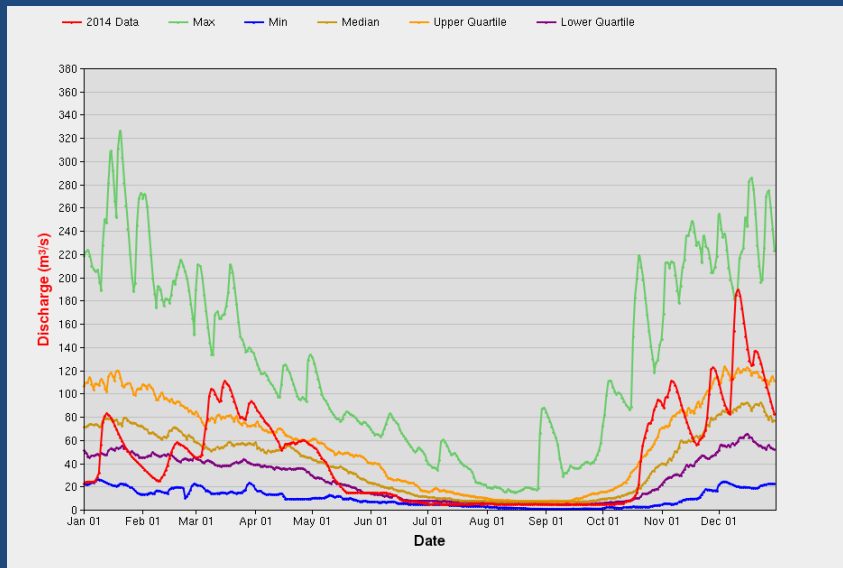
Wateroffice



Canada



Hydrologic Statistics



COWICHAN RIVER AT LAKE COWICHAN

- Expand understanding with longer records
- “Normal” and average conditions
- Peak-flows
- Monthly flows
- Low-flows
- Trends

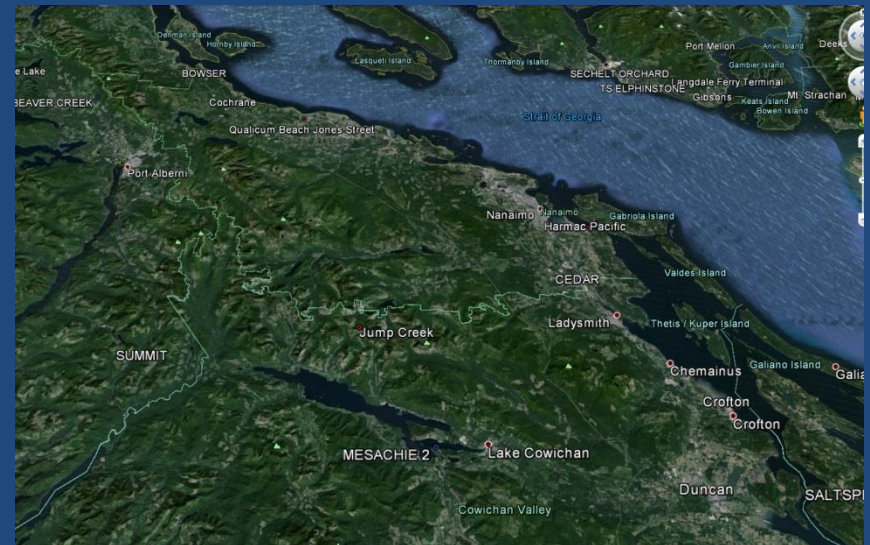
Climate and Weather Monitoring

- Temperature
- Precipitation
- Wind Speed
- Humidity
- Solar Radiation
- Statistics



Climate Related Monitoring

- Environment Canada
- Climate-Related Monitoring Program (CRMP)
 - Fire Weather Stations
 - Snow Pillow Network
 - Air Quality Monitoring
 - BC Hydro
 - Transportation/Highways
 - Agriculture

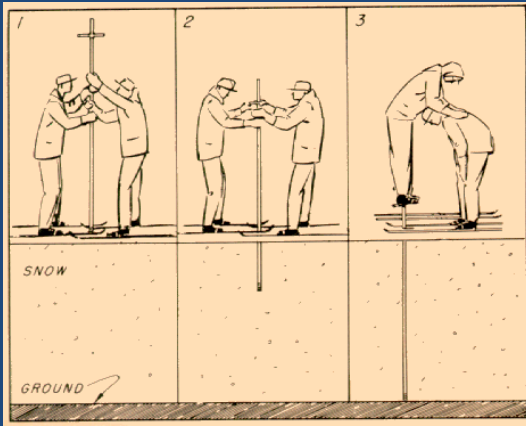


Snow Monitoring

- Co-ordinated by the Ministry of Environment
- Manual Snow Surveys (since 1930's)
- Automated Snow Pillows (late 1960's)



What is a Snow Survey?

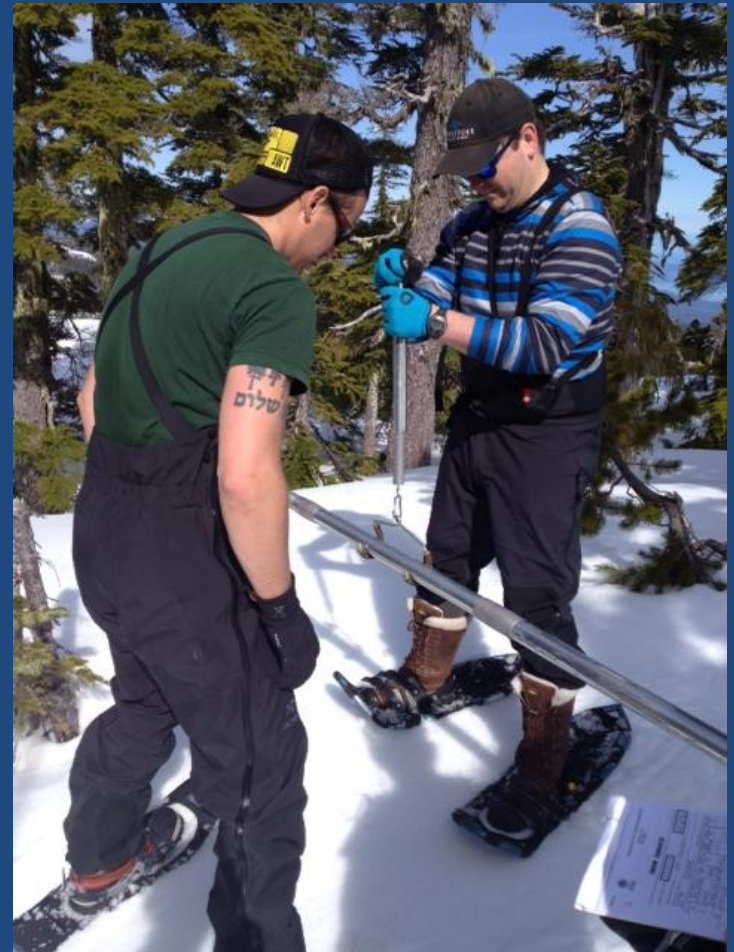


- Standard Snow Sampler
- Core sample taken
- Weighed
- Depth, Mass, Density, Snow Water Equivalent
 - Depth of water if melted (usually in mm)
- Repeat measurement at 4-10 points at one location (set locations)



Manual Snow Surveys

- Manual Snow Surveys (Jan 1, Feb 1, Mar 1, Apr 1, May 1, May 15, Jun 1, Jun 15)
- Up to 155 surveys per period



Automated Snow Pillow

- 3 m diameter bladder (“Pillow”) filled with glycol solution



Automated Snow Pillow

- Displaces solution when loaded



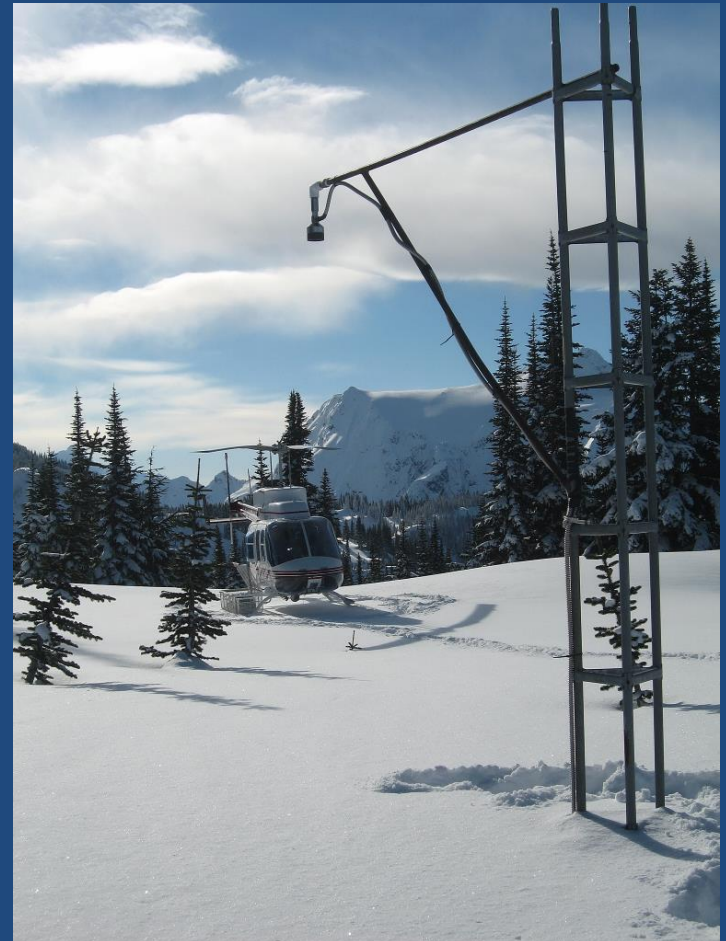
Automated Snow Pillow

- Record displacement with shaft encoder



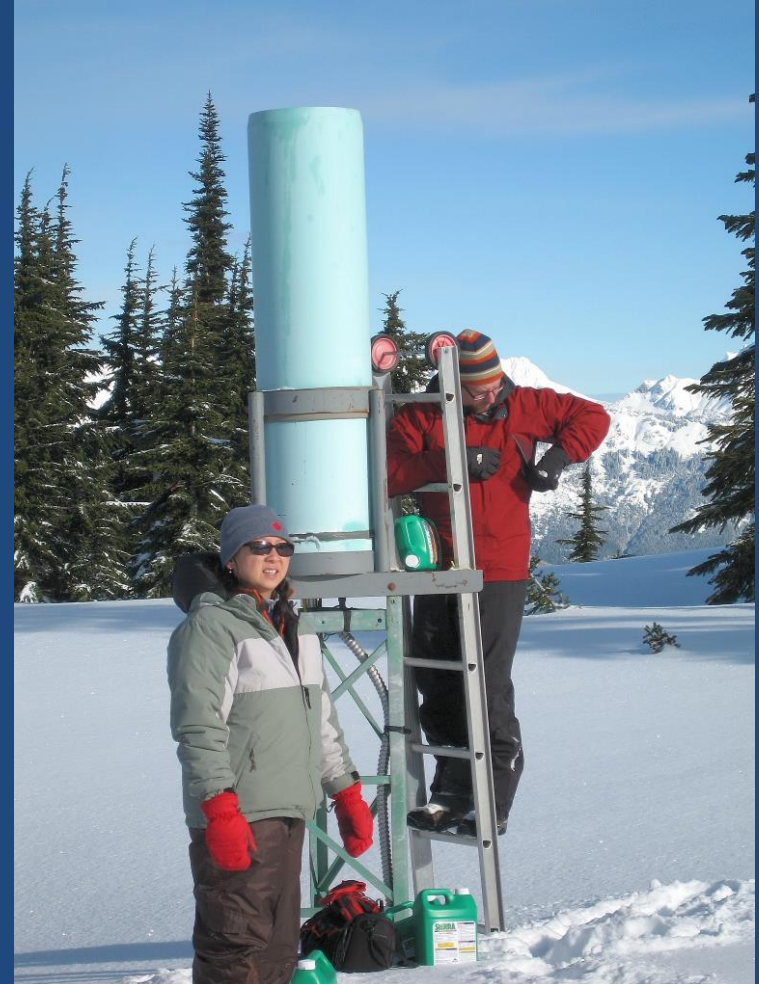
Automated Snow Pillow

- Snow Depth Sensor
 - Ultrasonic sensor (measures distance)



Automated Snow Pillow

- Total Precipitation Gauge
 - PVC pipe with propylene glycol solution
 - Inhibits freezing
 - Requires maintenance
- Records accumulated precipitation



Automated Snow Pillow

- Temperature Sensor
- Solar-powered charge of deep cell marine batteries



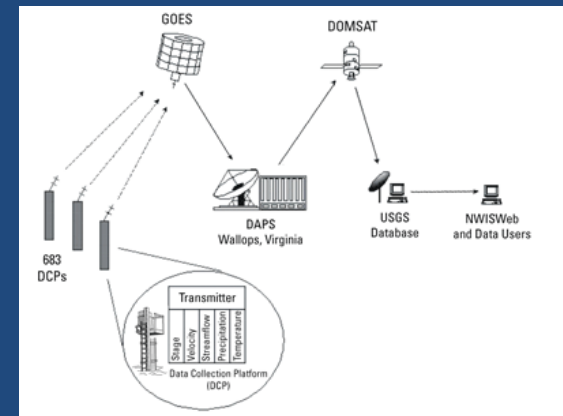
Automated Snow Pillow

- Equipment House for data logger
- <https://www.youtube.com/embed/ud-xYJC0dKA>



Automated Snow Pillow

- Antenna for satellite transmission
- Transmitted on GOES satellite network
- Data captured and decoded by the RFC



Automated Snow Scale

- Sommer snow scale
- Weighs snow
- Similar to snow pillow but easier to install
- Limits on weight (challenge in Coastal snow packs)
- Snow bridging can affect measurement



Snow Monitoring

- 62 Automated sites around the province
- Provide “real-time” observations of snow depth, snow water equivalent, temperature and total precipitation
- Useful for accumulation (particularly “in-between” snow survey periods)
- Invaluable for snow melt



A year in the life....

- <https://www.youtube.com/watch?v=ud-xYJC0dKA&feature=youtu.be>

Automated Snow Pillow (ASP) Data

Snow Survey Basin Areas

Where am I? < Back to menu

Map Satellite

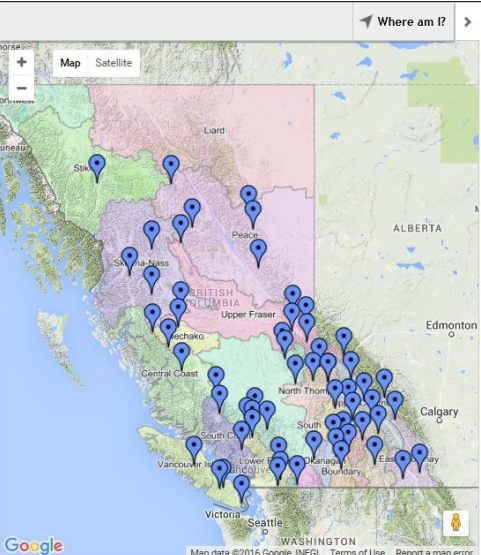
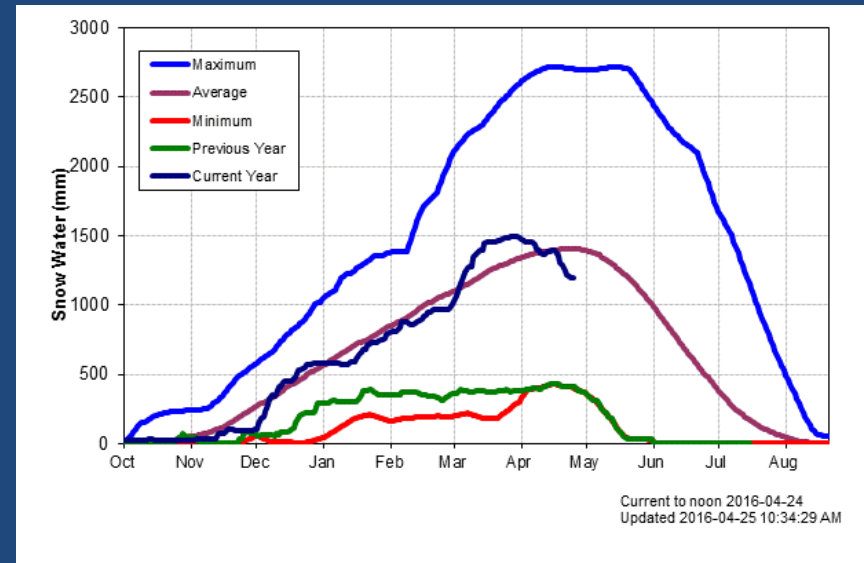
Find a Snow Pillow

BASIN_NAME
--Search All--

STATION_ID
--Search All--

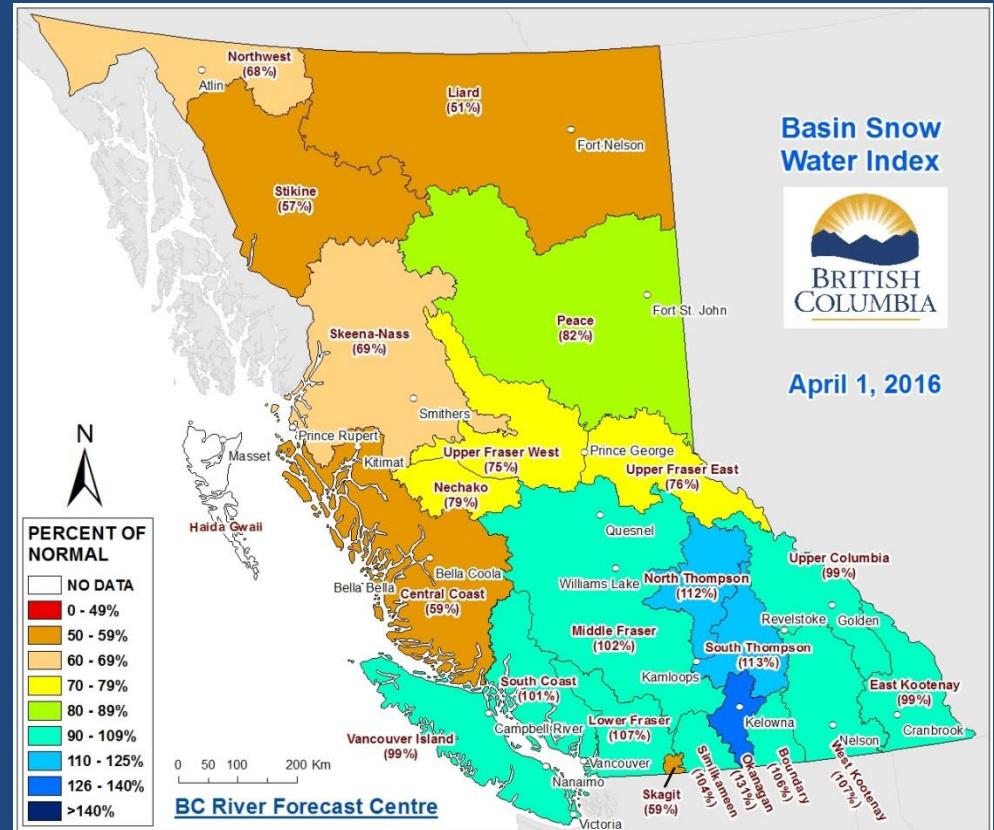
NAME
--Search All--

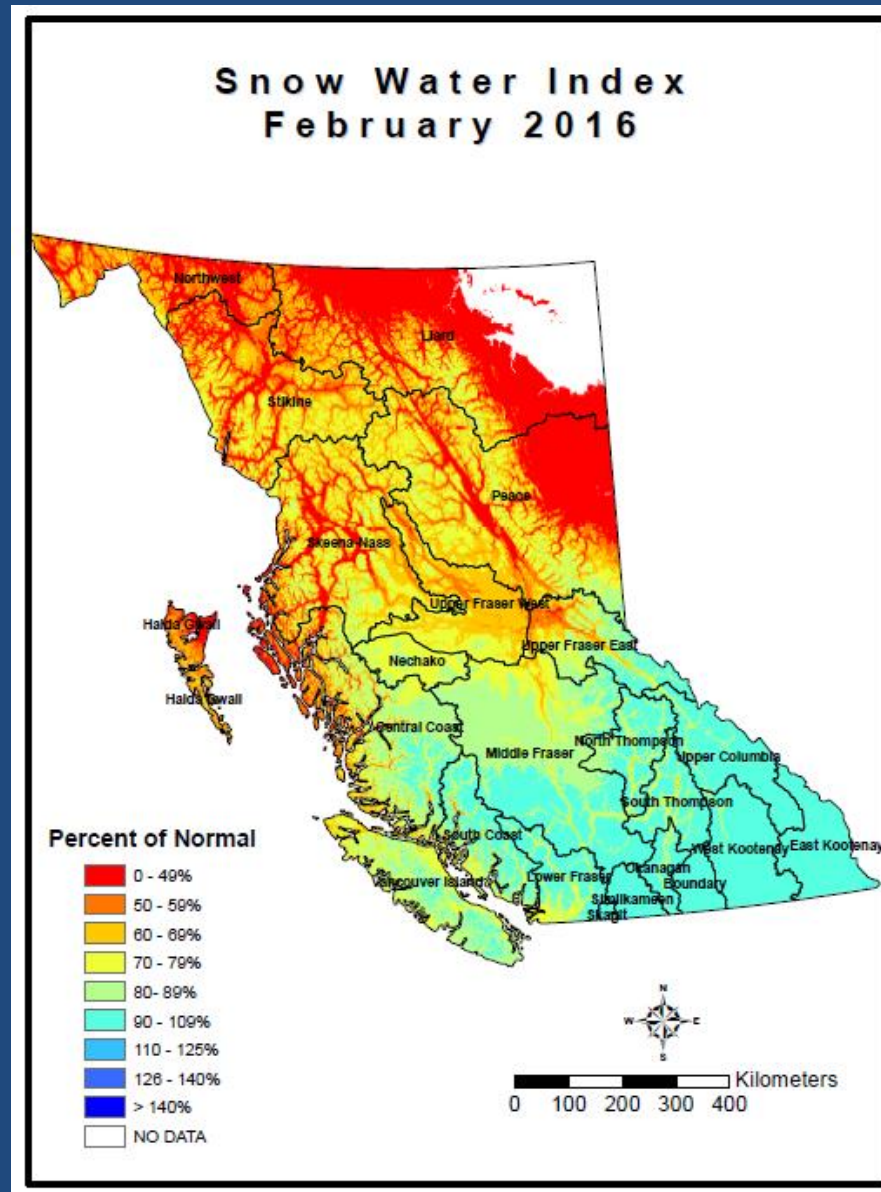
Search

3B17P - WOLF RIVER (UPPER)

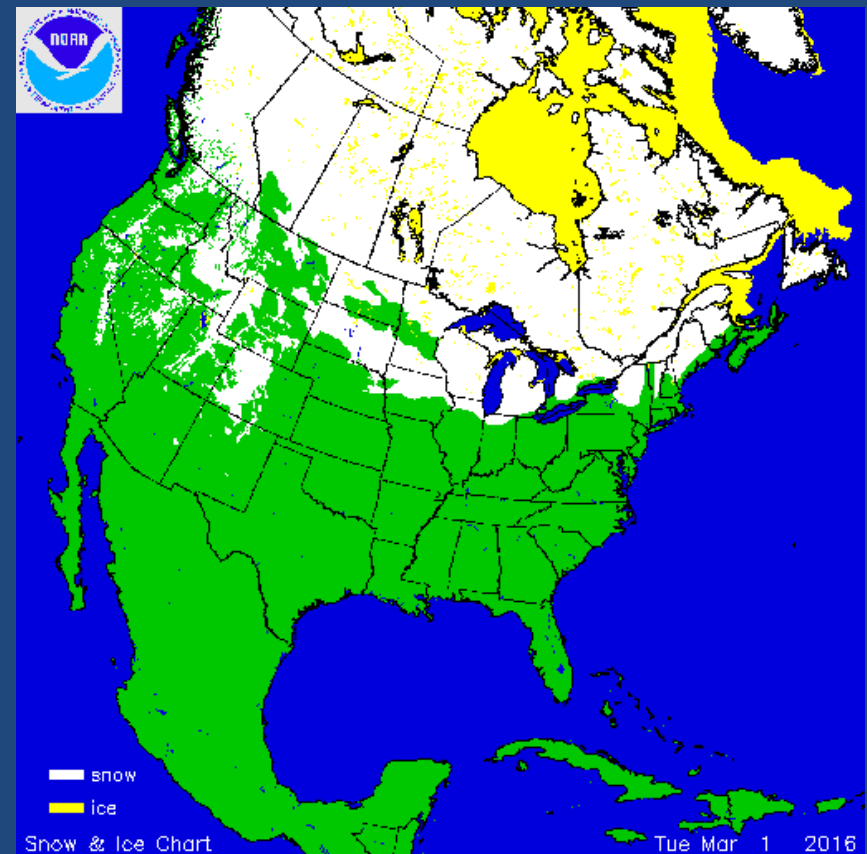
- Basin Analysis
 - Index Approach
 - Coarse-resolution



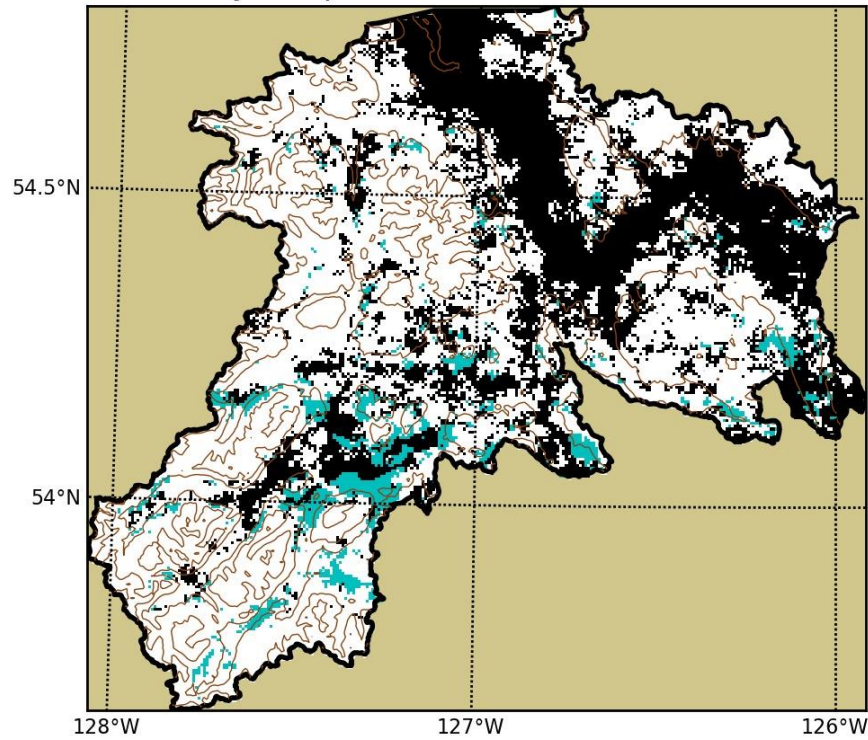


Remotely-Sensed Snow Pack

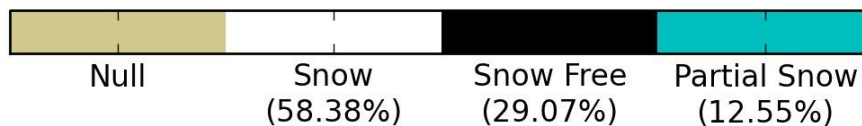
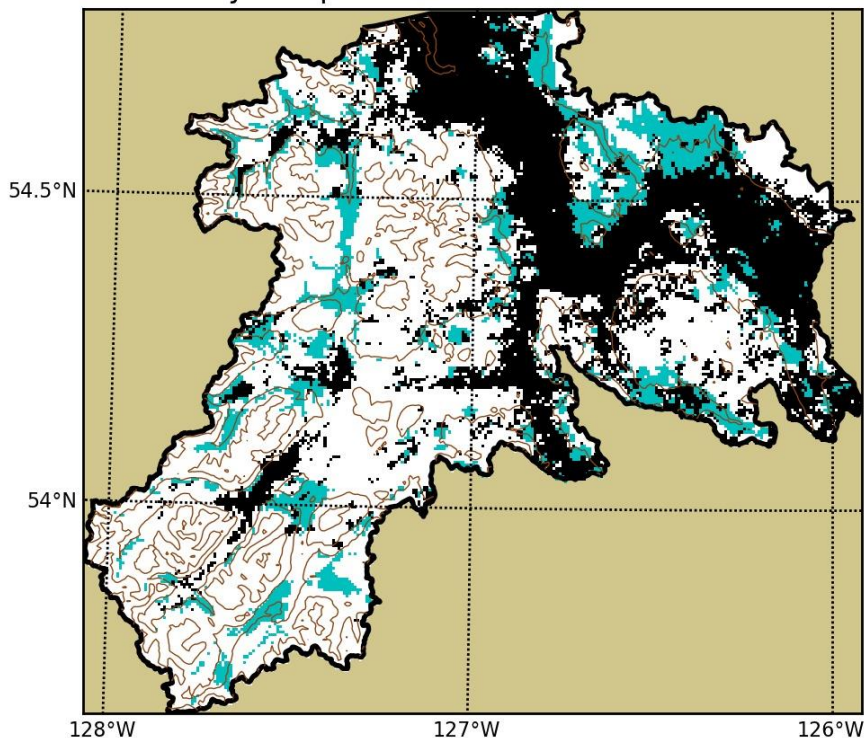
- Benefits
 - Can get up-to-date information on snow co
- Challenges
 - Cloud cover
 - Resolution
 - Snow cover vs. SWE



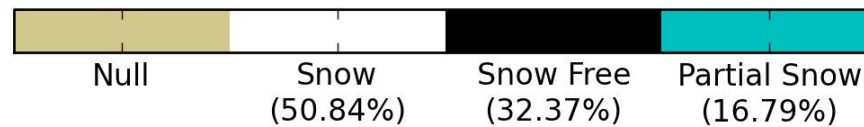
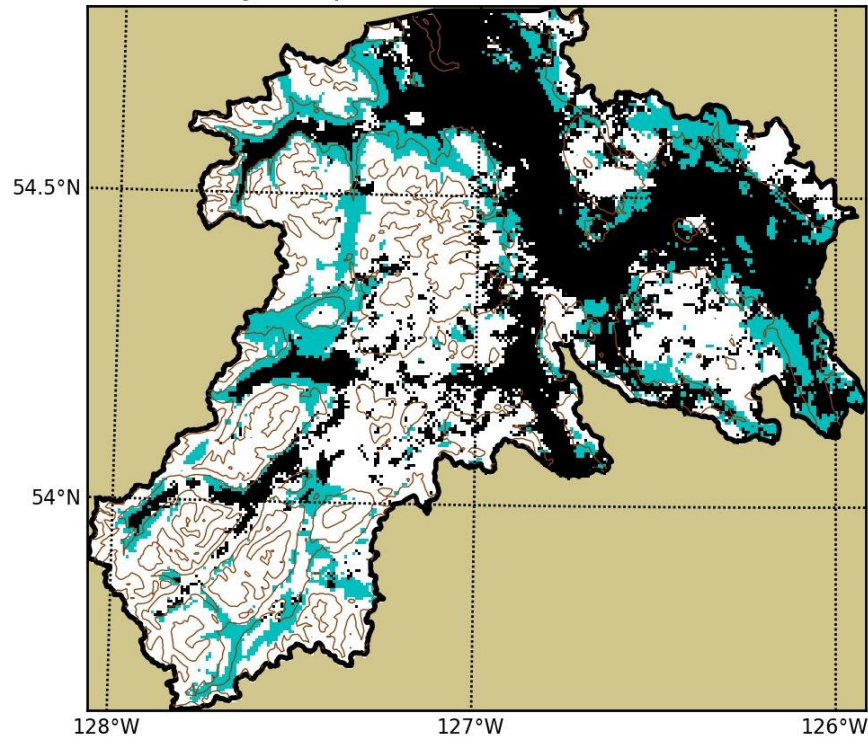
SNOWL 8-day composite snow cover: BULKLEY 2012-4-23



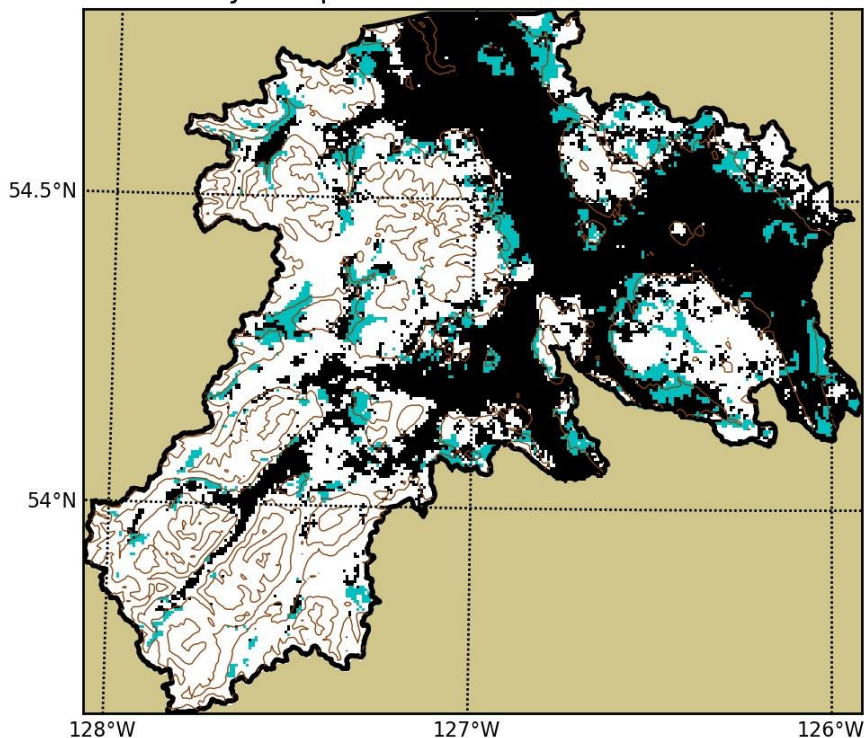
SNOWL 8-day composite snow cover: BULKLEY 2012-4-29



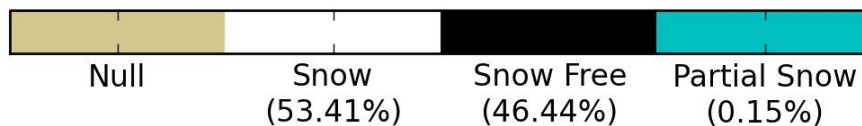
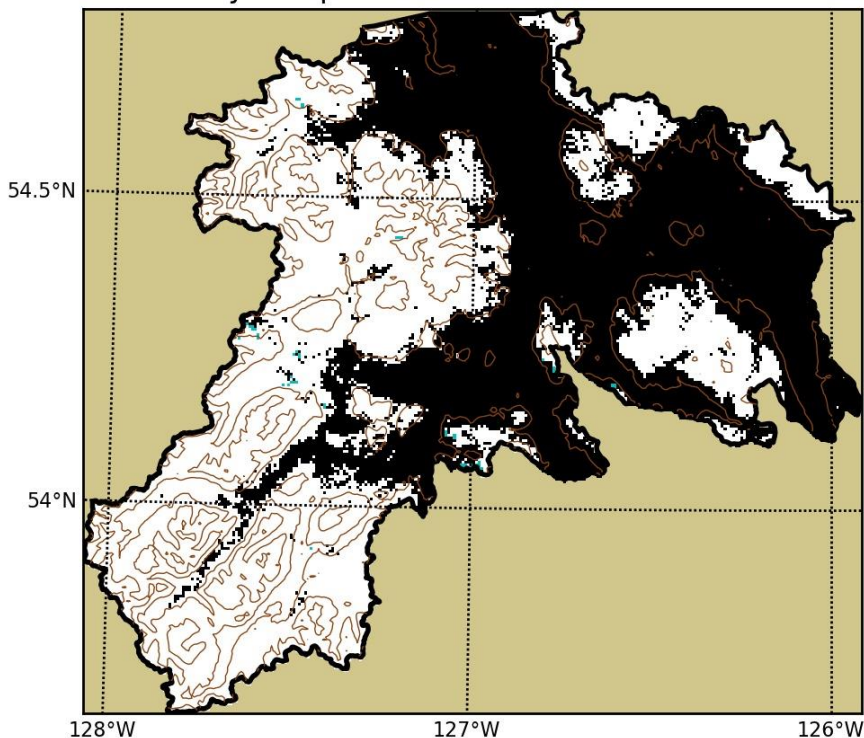
SNOWL 8-day composite snow cover: BULKLEY 2012-5-6



SNOWL 8-day composite snow cover: BULKLEY 2012-5-13

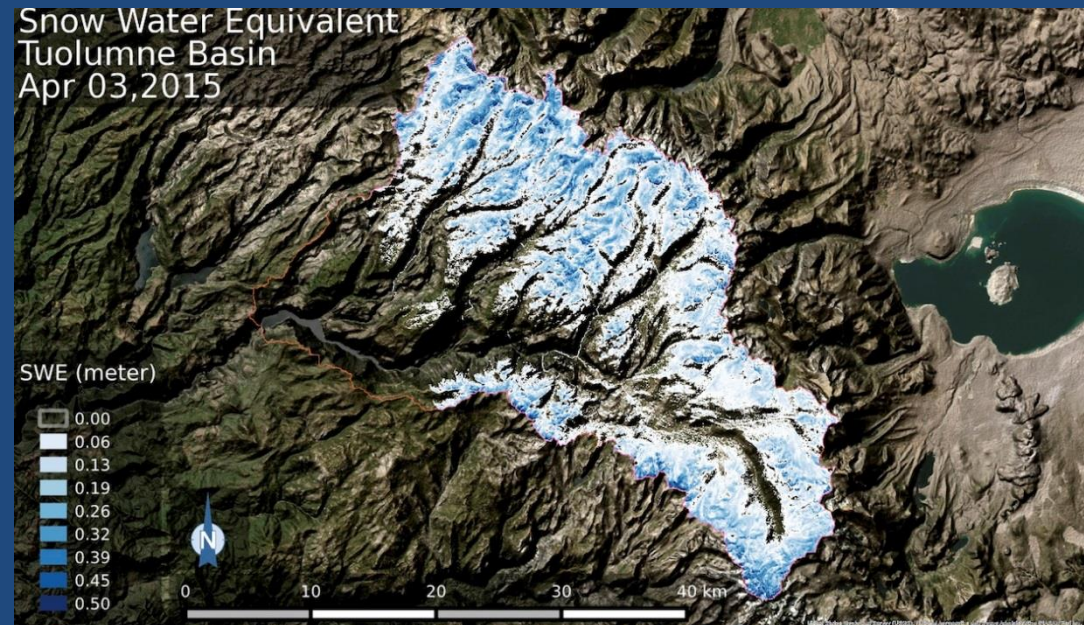


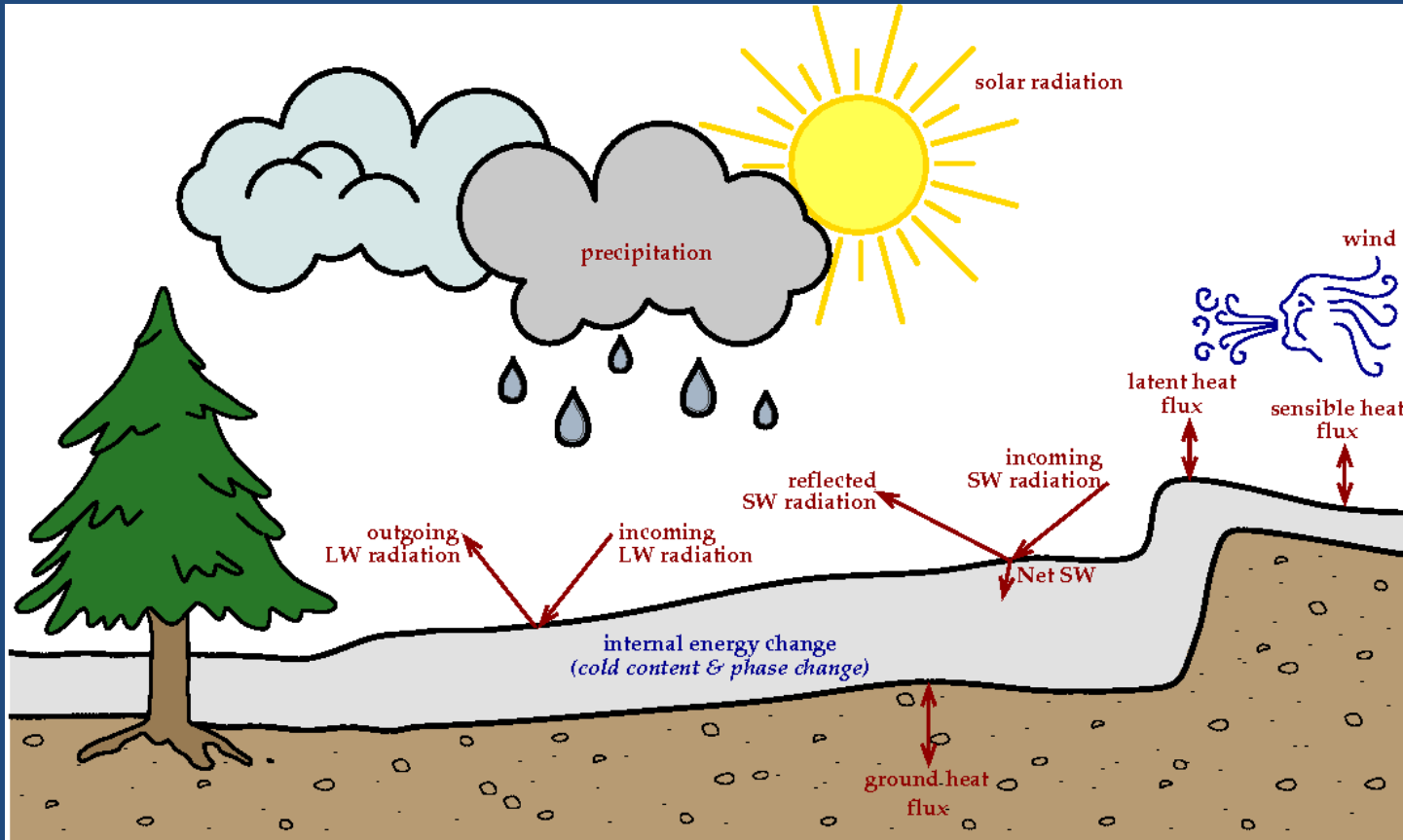
SNOWL 8-day composite snow cover: BULKLEY 2012-5-21



Airborne Surveys

- LiDAR (light detection and ranging)
- Repeat measurements and examining changes in snow cover (depth)
- Apply density analysis to calculate SWE





$$\Delta H = H_{rs} + H_{rt} + H_s + H_l + H_g + H_p \quad [11-1]$$

where:

- H_{rs} = net solar radiation
- H_{rt} = net thermal radiation
- H_s = sensible heat transfer from air
- H_l = latent heat of vaporization from condensation or evaporation/sublimation
- H_g = conducted heat from underlying ground
- H_p = advected heat from precipitation

Energy Balance Approach

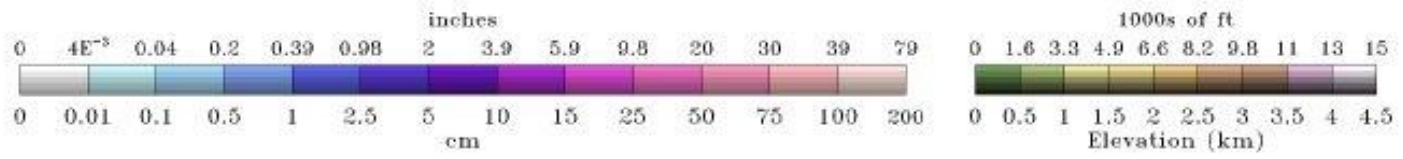
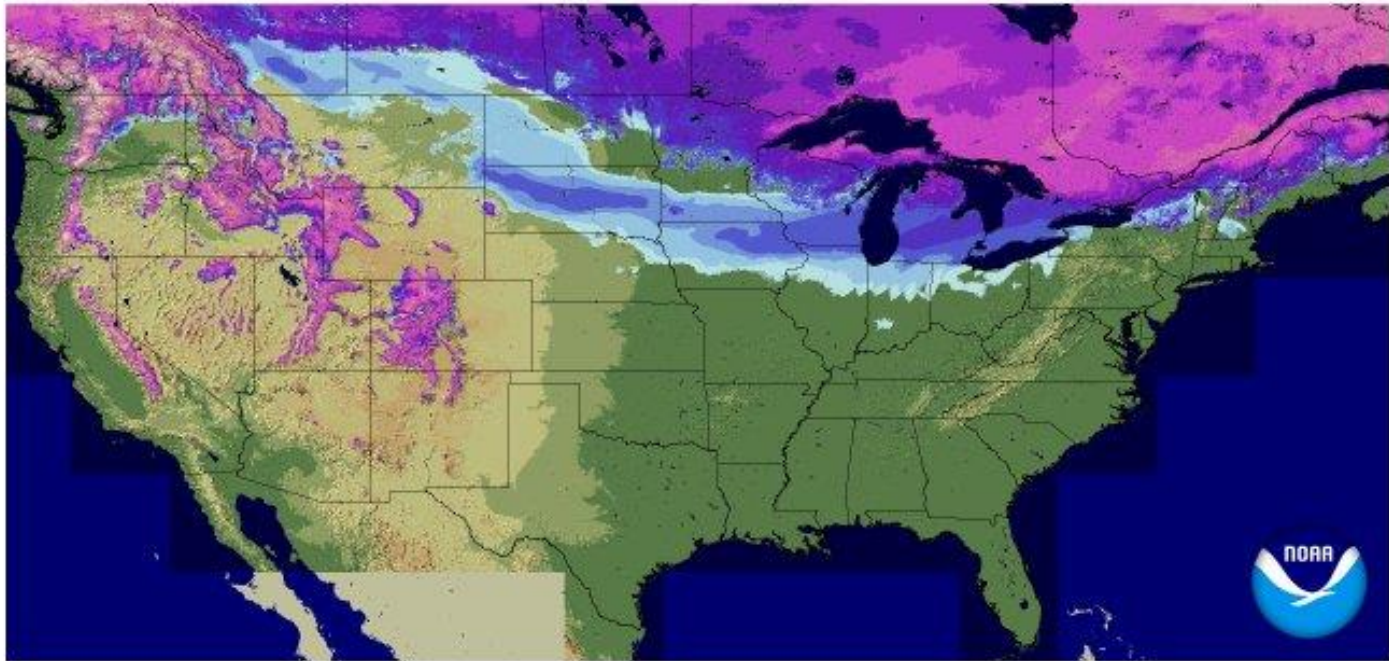
Modelling SWE

National Snow 2015-
Analysis 2016

NATIONAL
WATER
CENTER
NWC

Snow Water Equivalent

2016-03-02 06 UTC





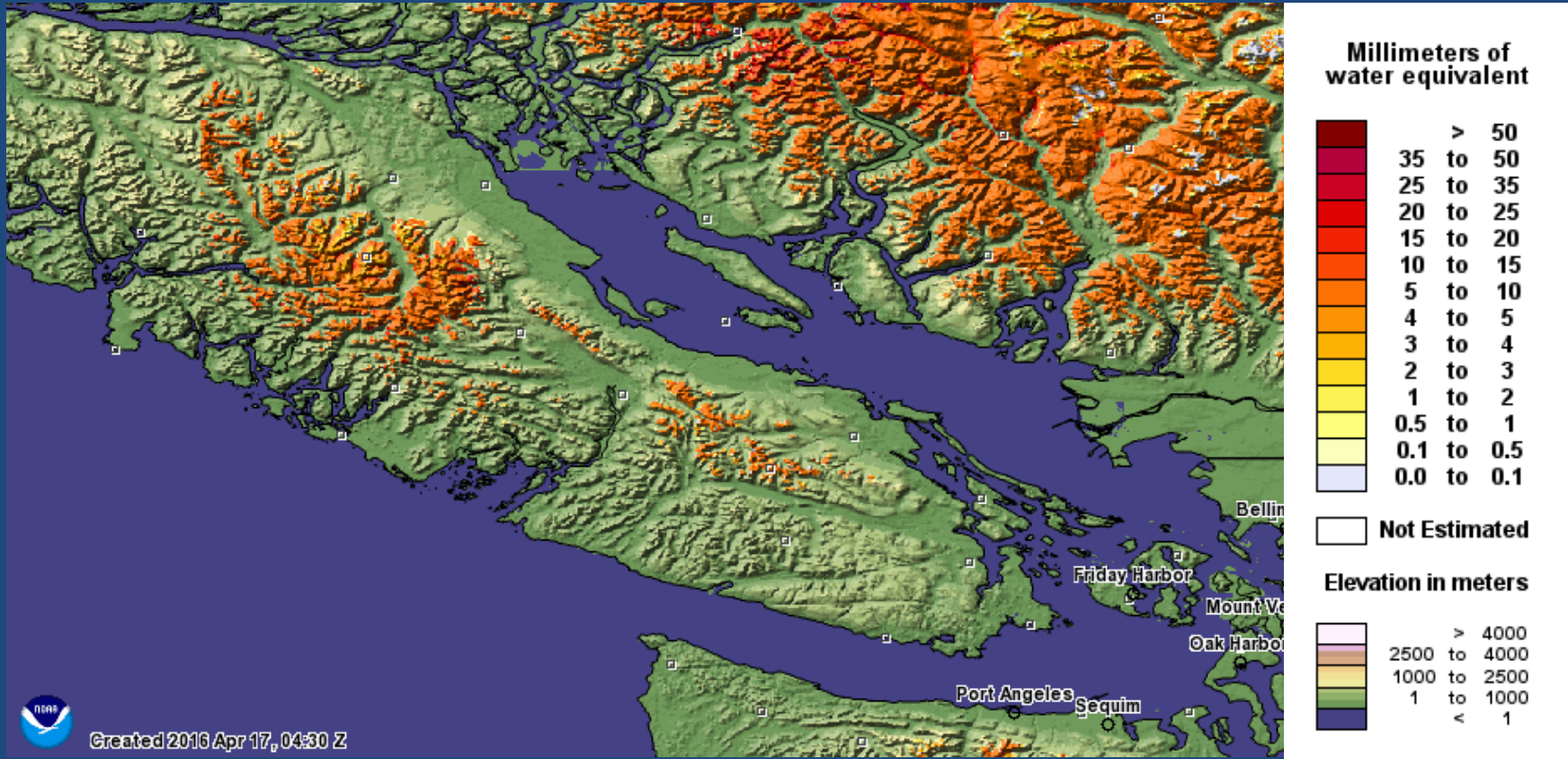
<http://www.nohrsc.nws.gov/interactive/html/map.html>



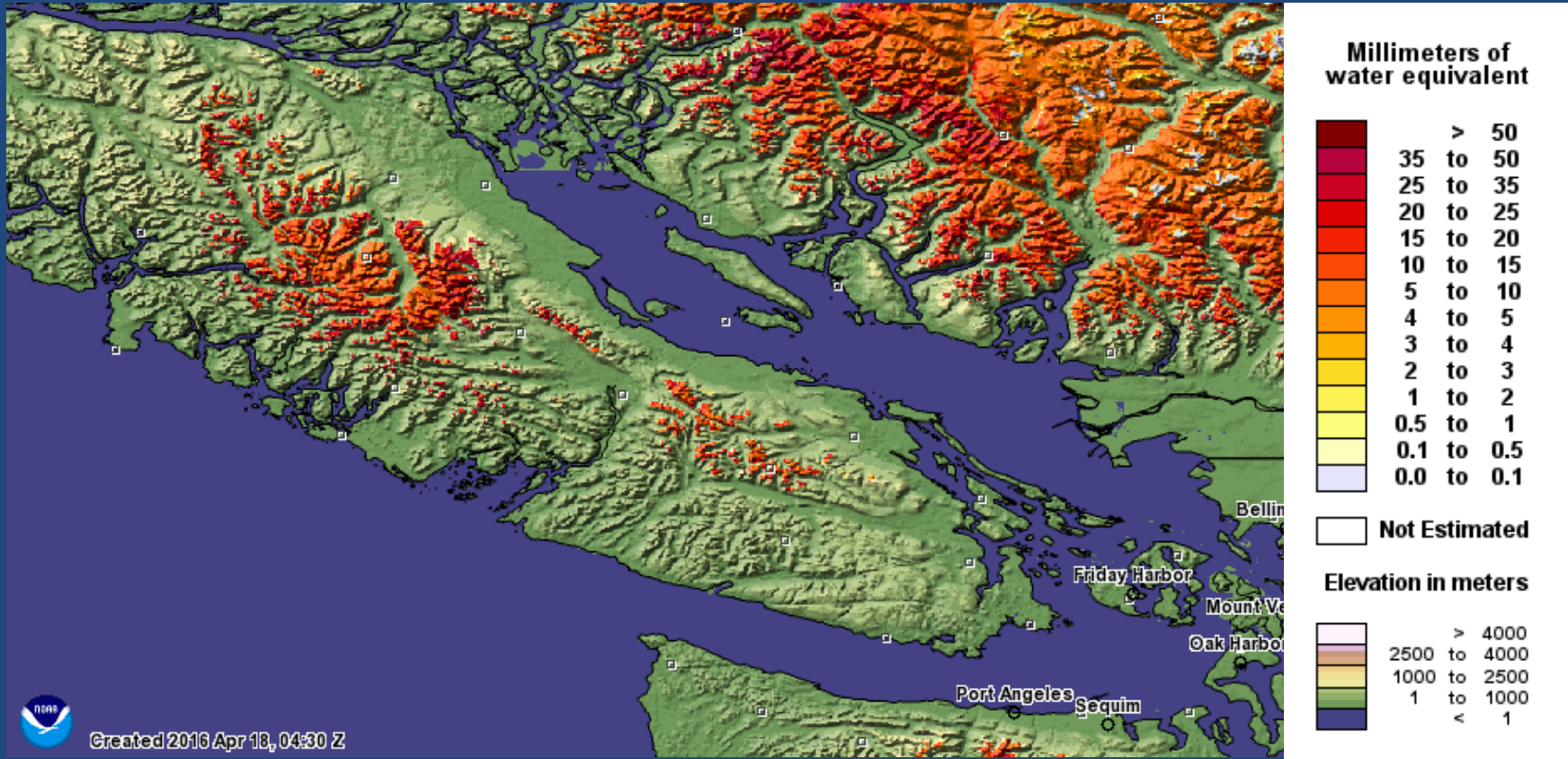
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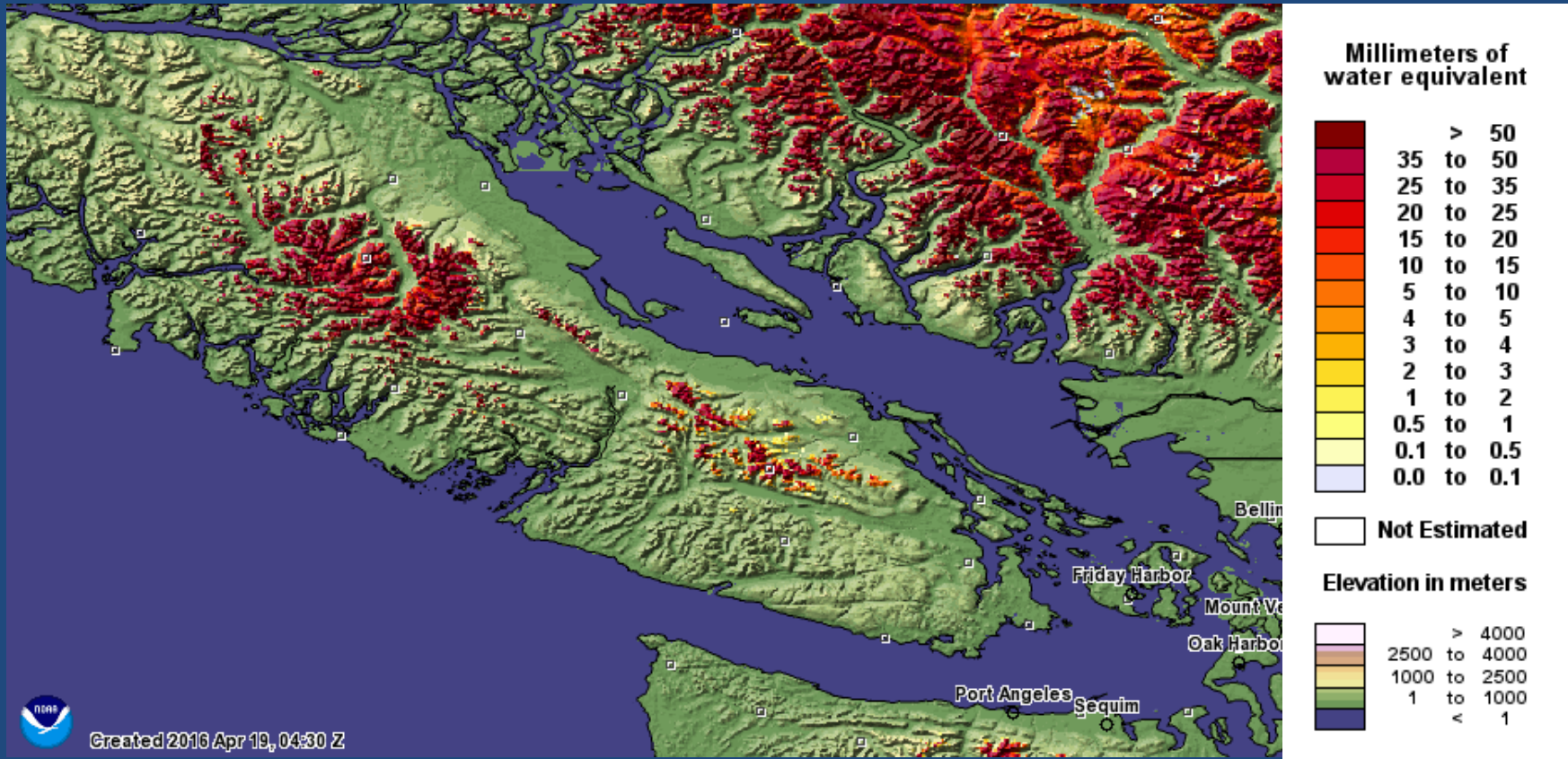
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<http://www.nohrsc.nws.gov/interactive/html/map.html>



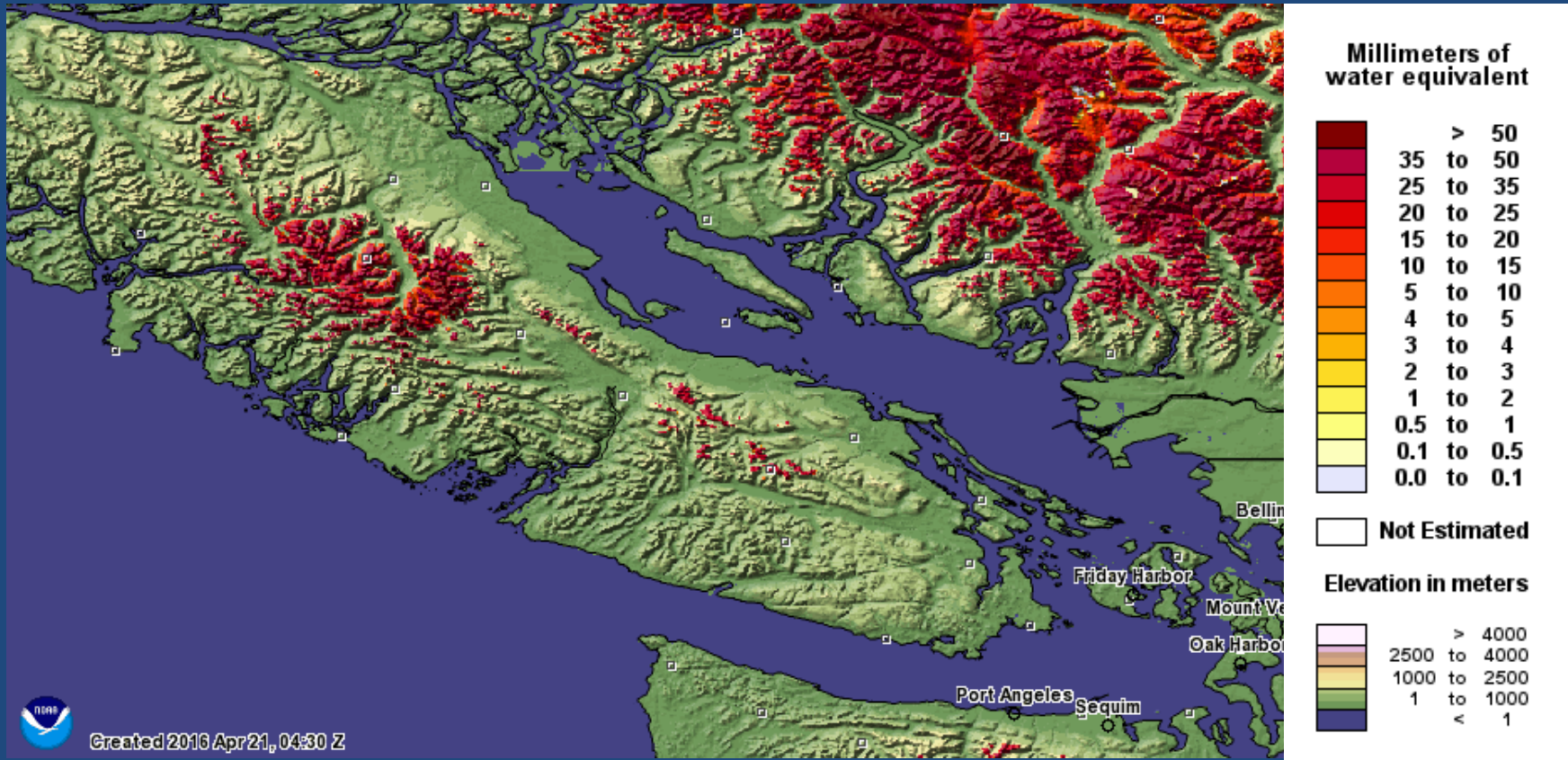
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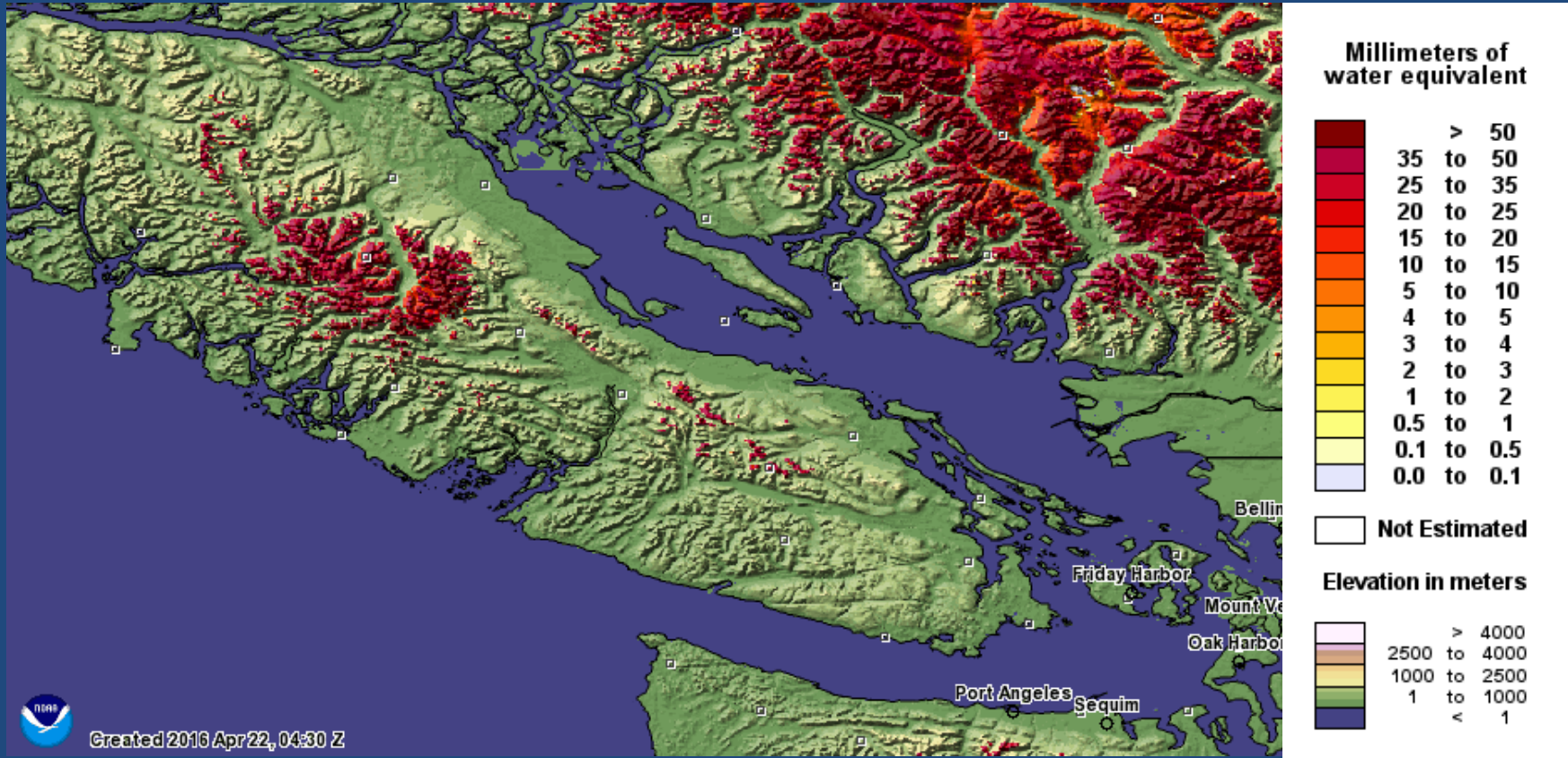
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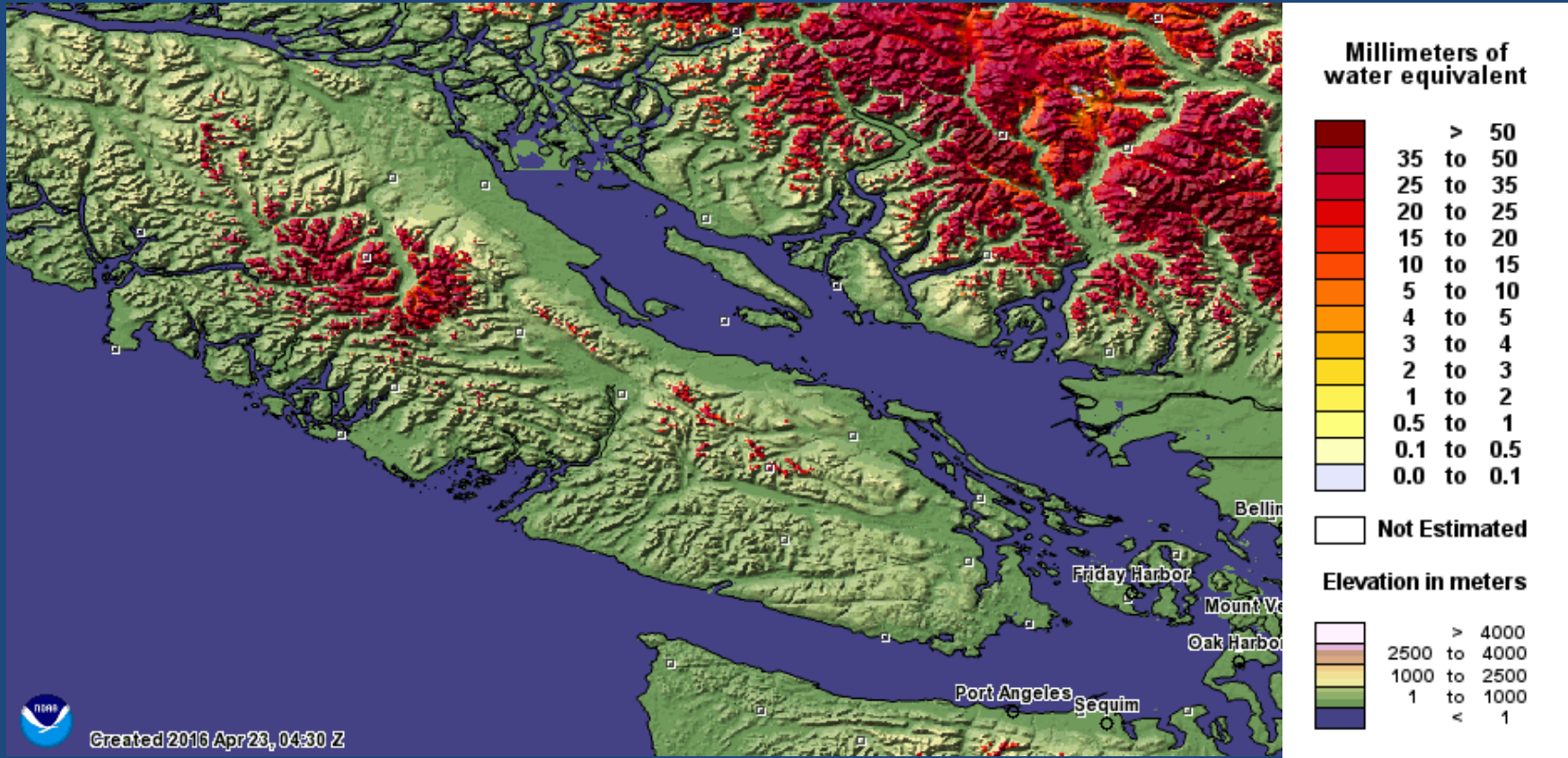
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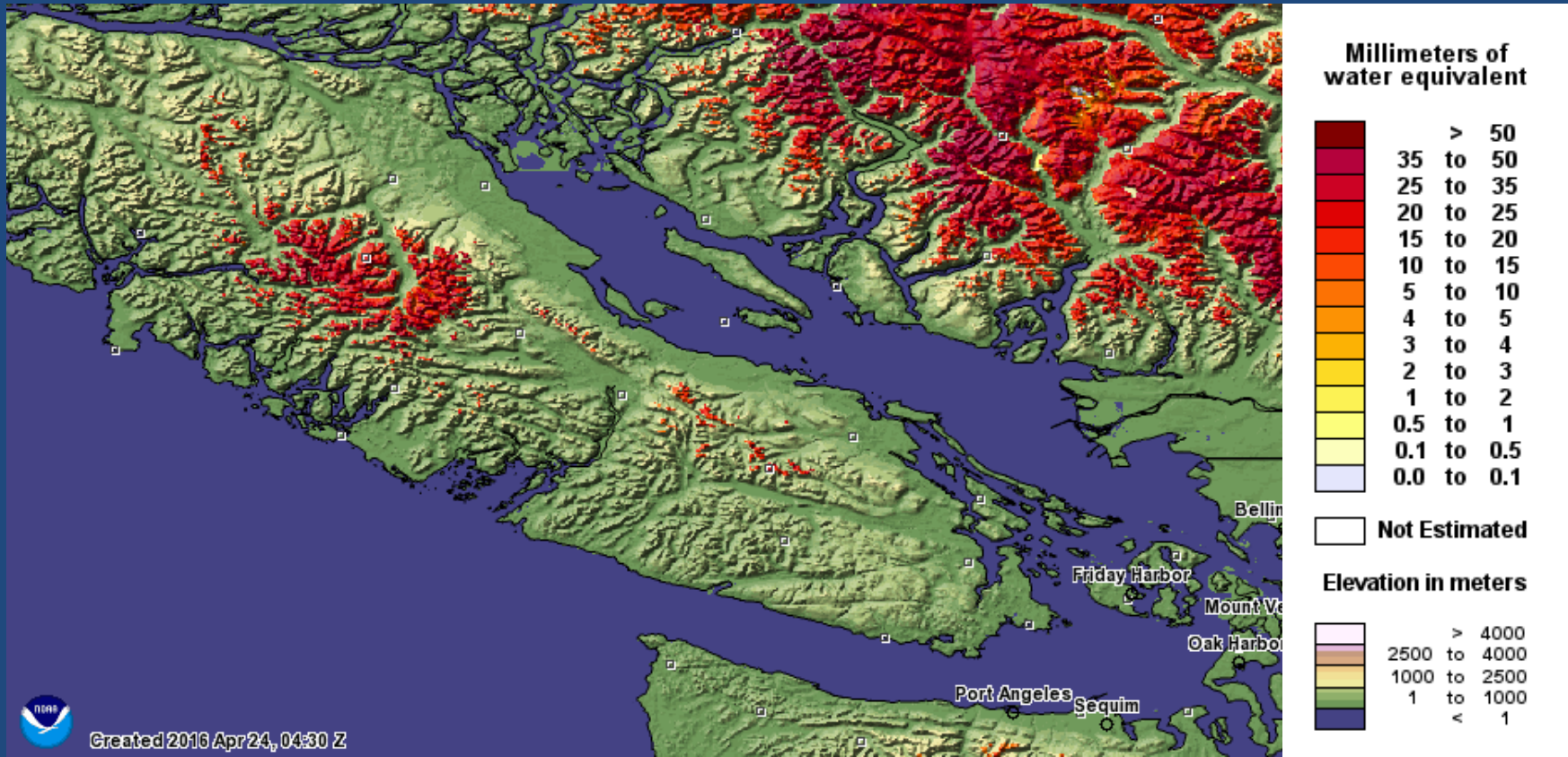
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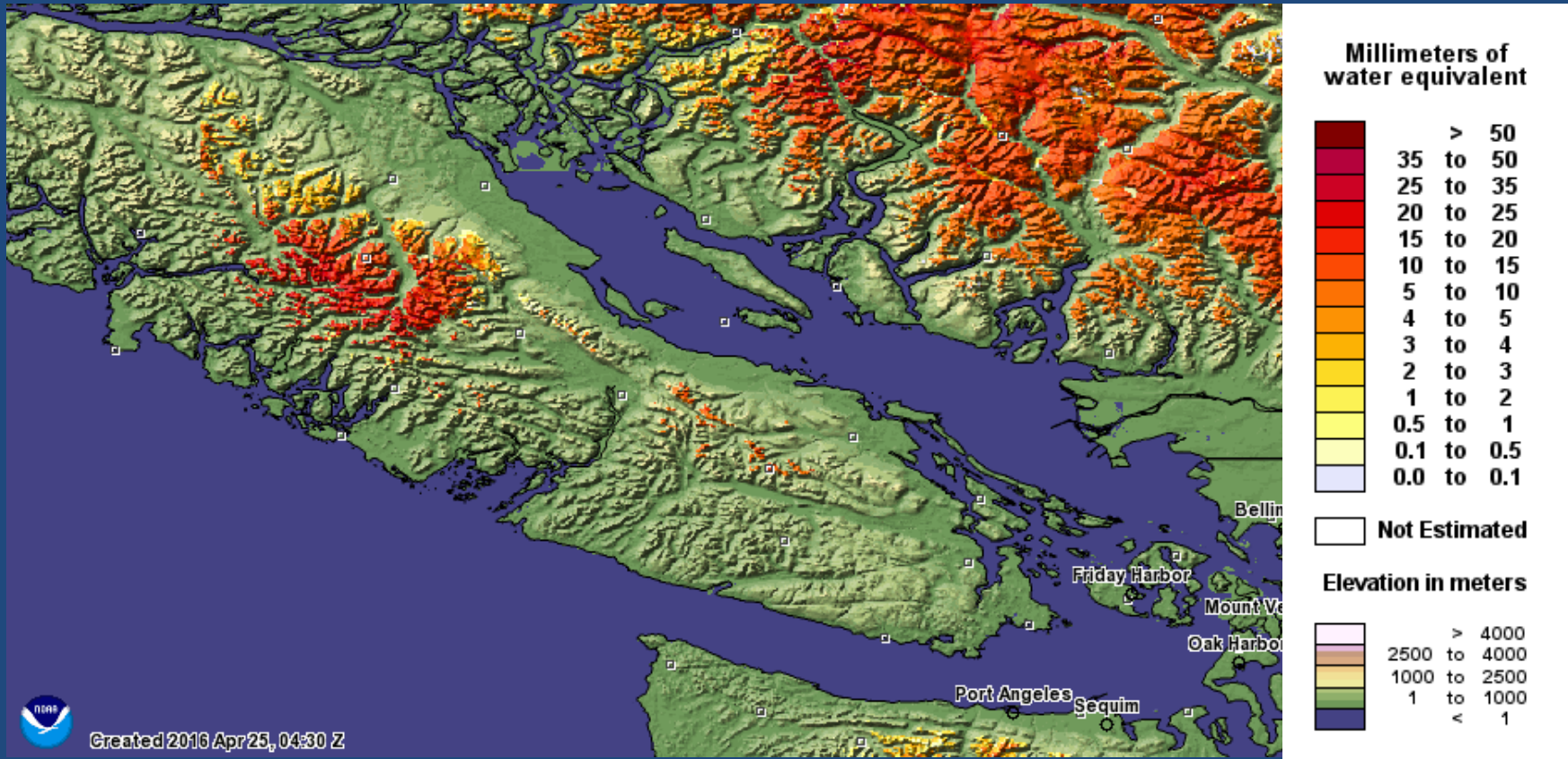
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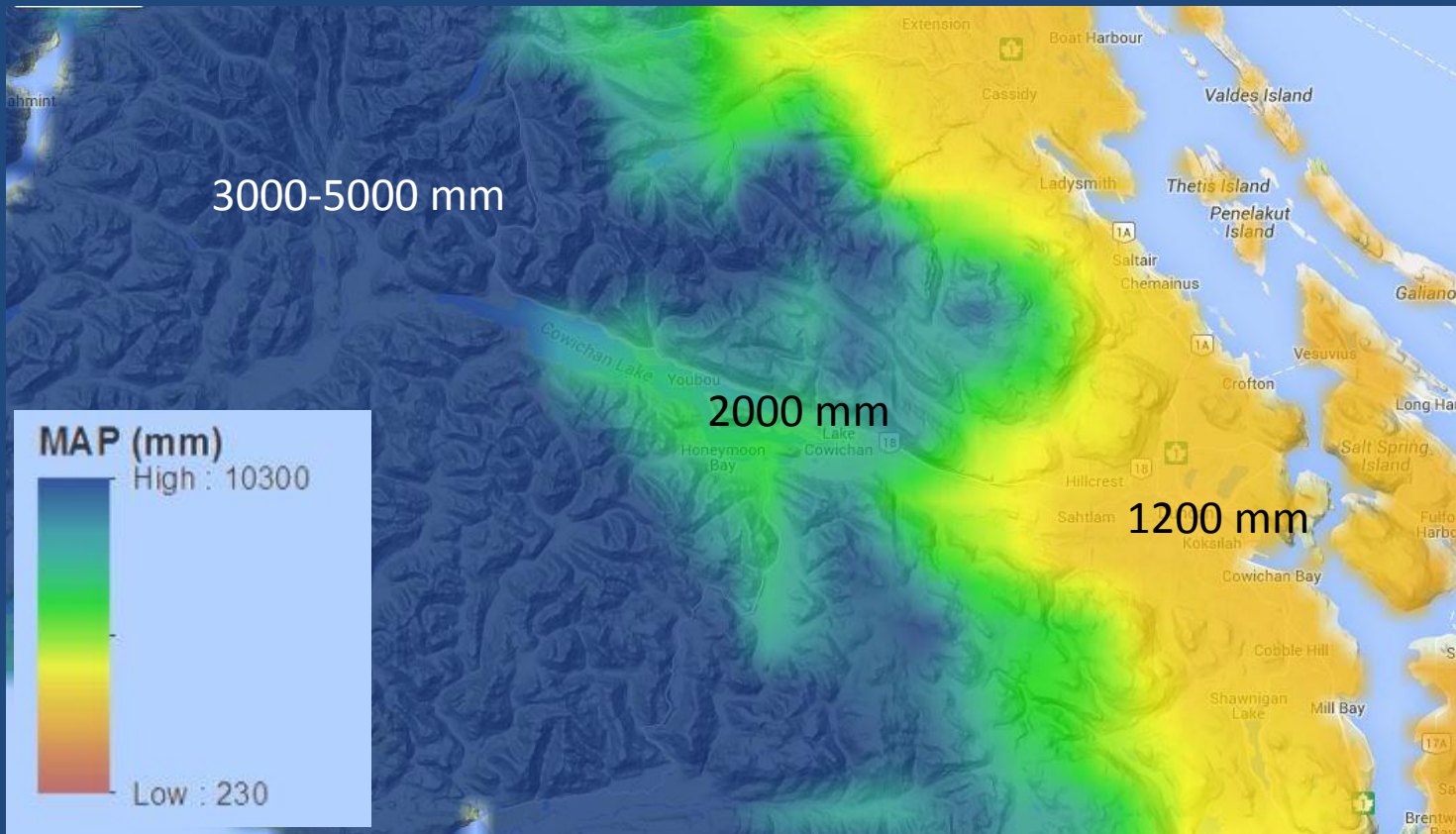


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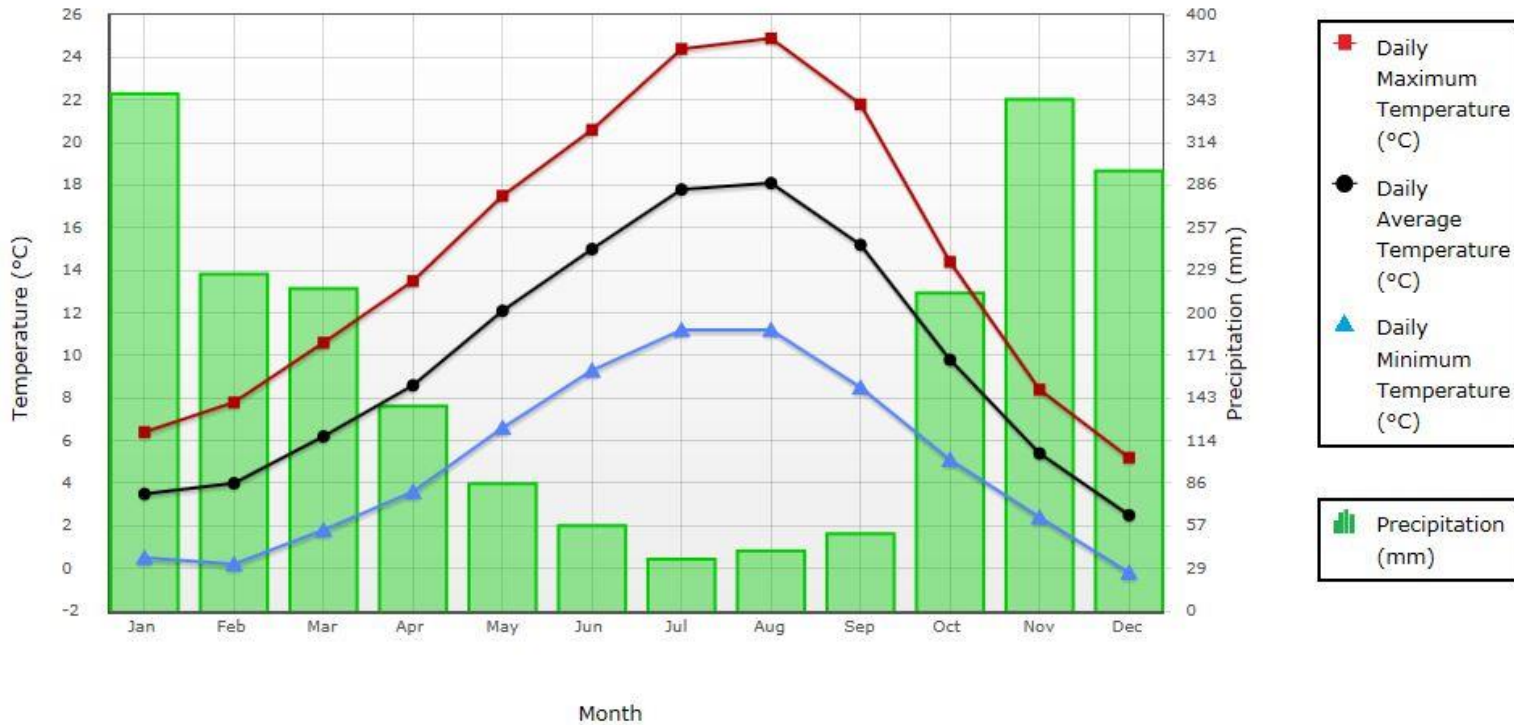


COWICHAN

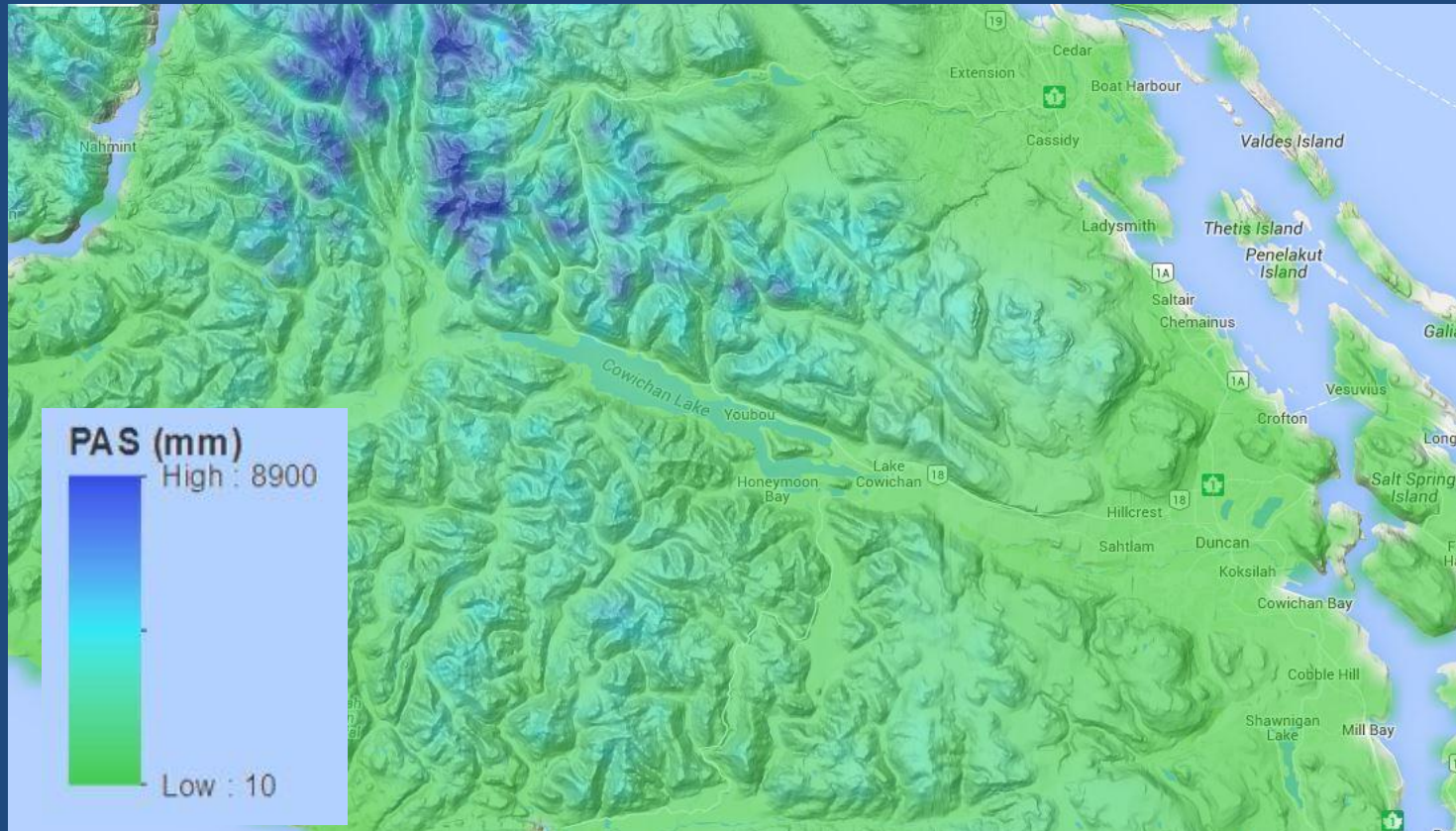
Annual Precipitation



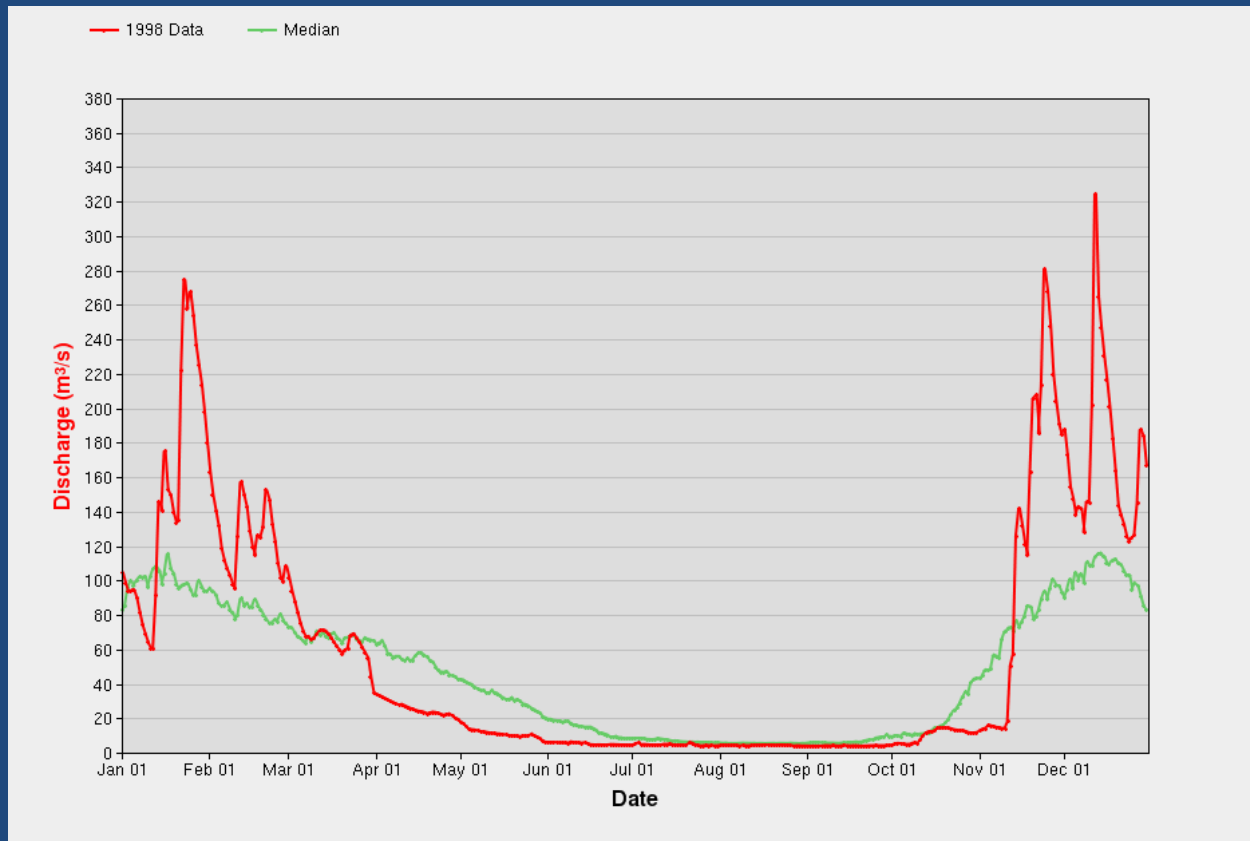
**Temperature and Precipitation Chart for 1981 to 2010 Canadian Climate Normals
LAKE COWICHAN**



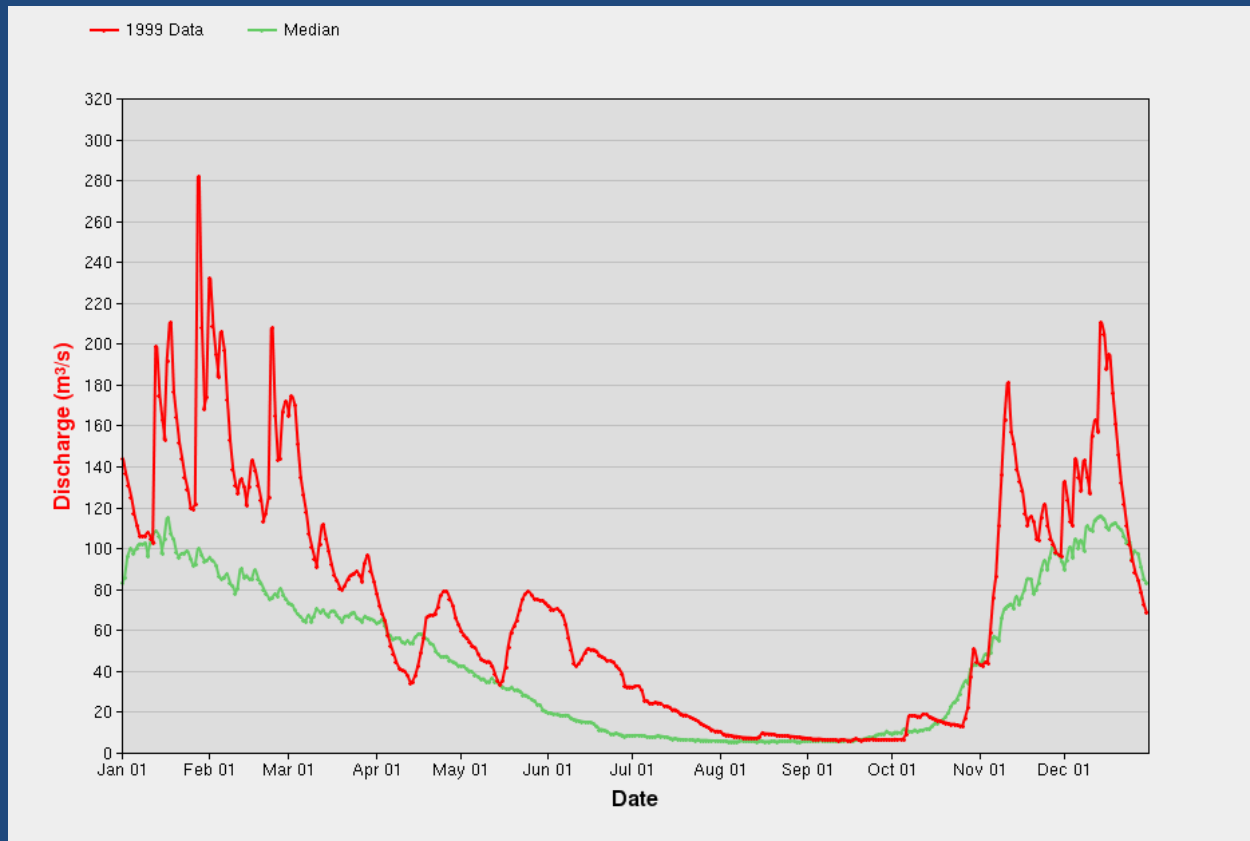
Precipitation as Snow



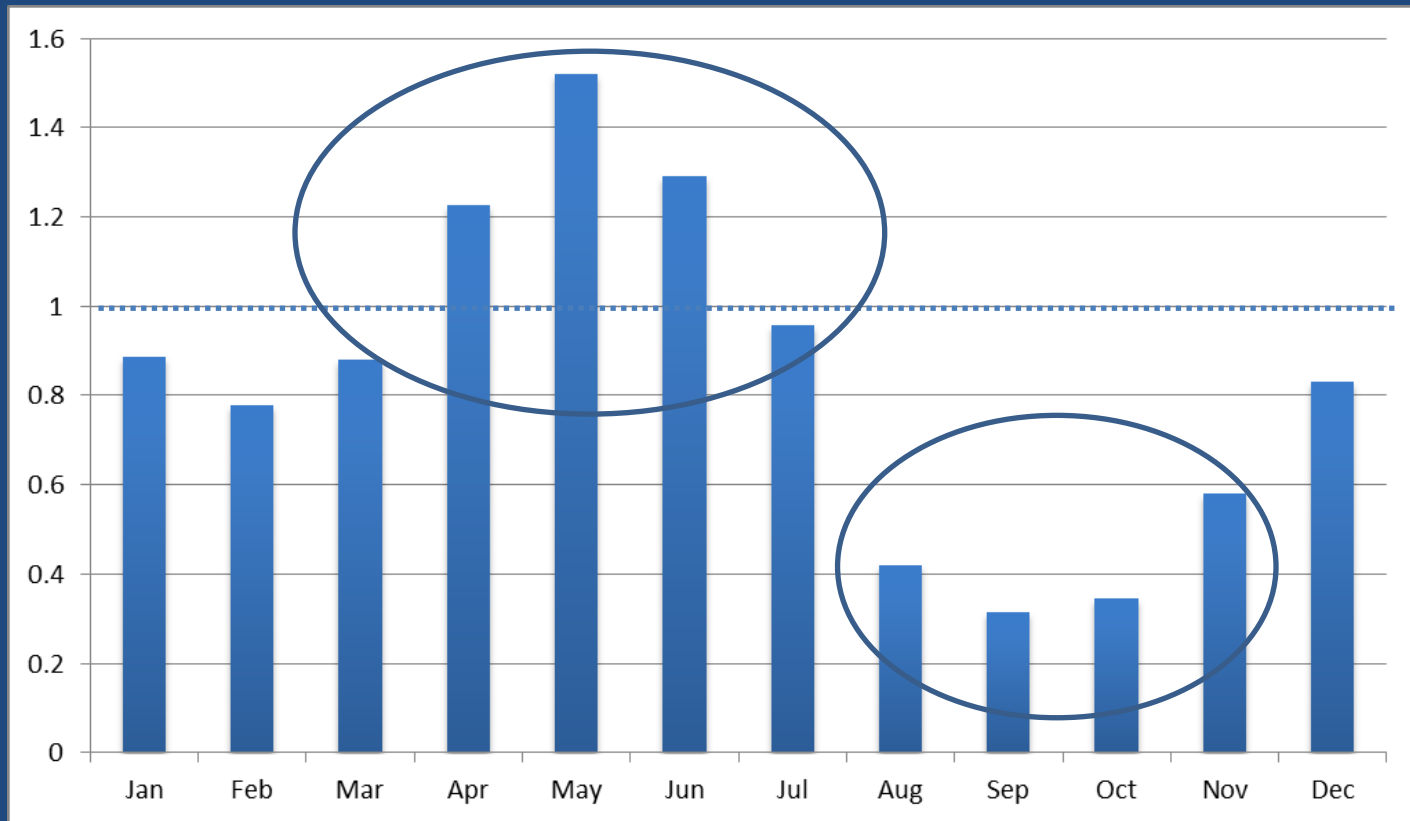
COWICHAN RIVER NEAR DUNCAN



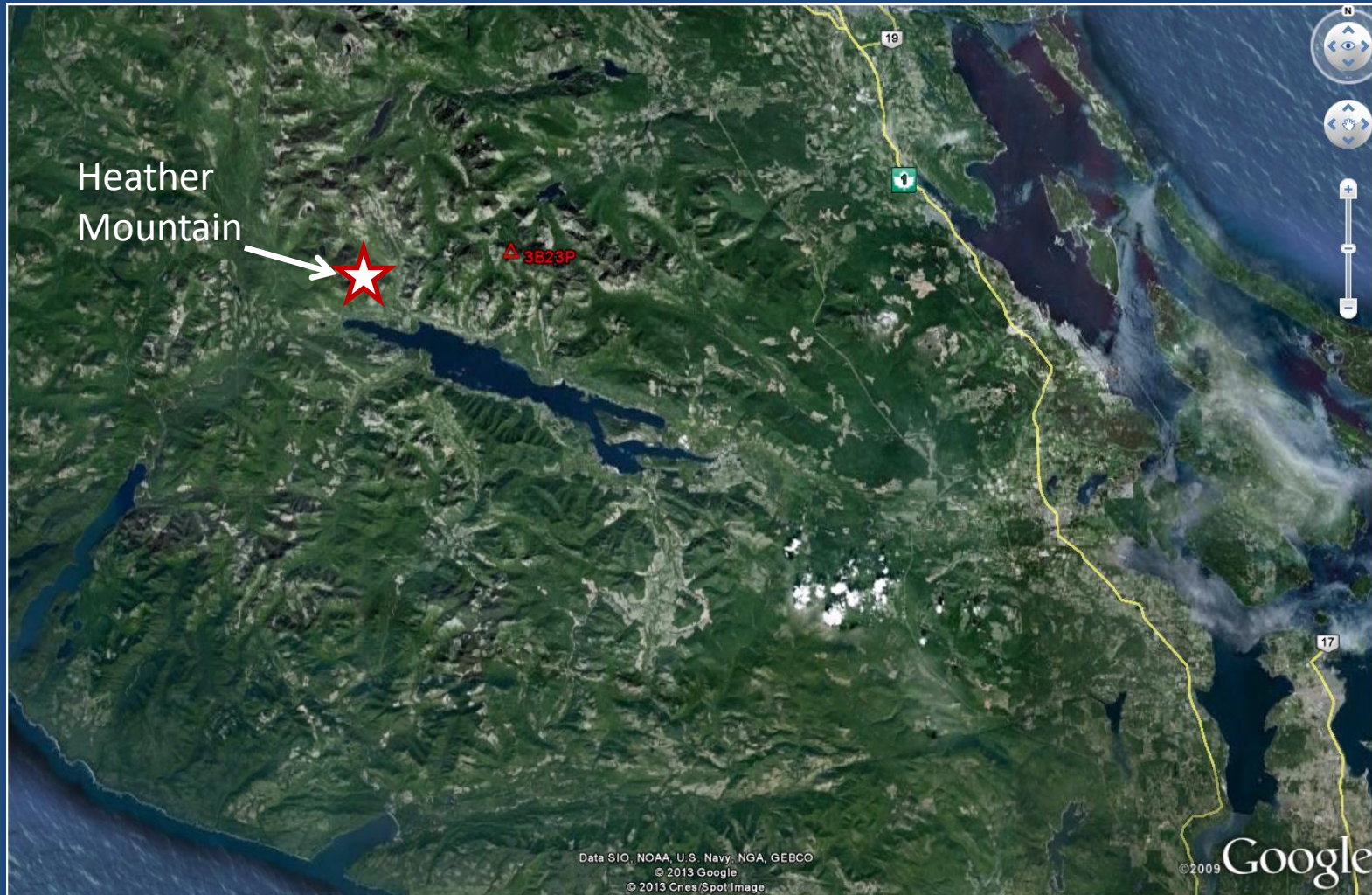
COWICHAN RIVER NEAR DUNCAN



Proportional Runoff

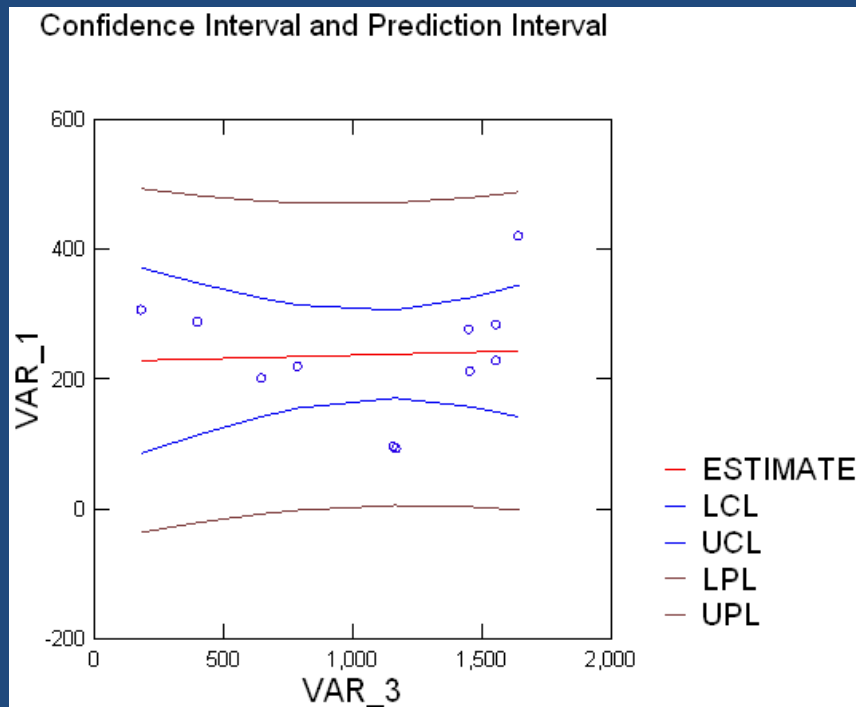


Vancouver Island Snow Monitoring Network

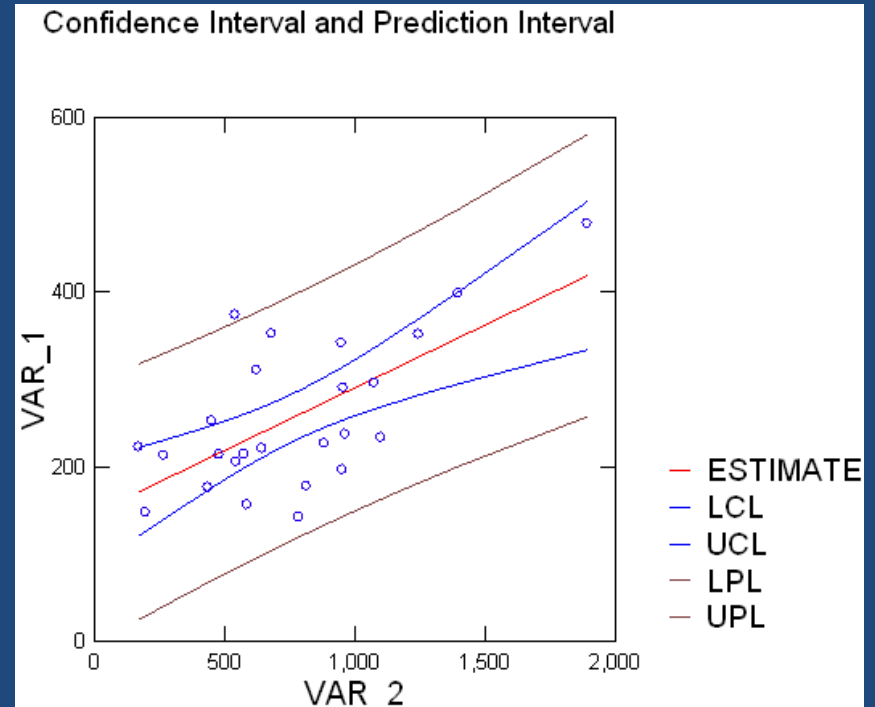


	Jump Creek ASP	Heather Mountain MSS
Period of Operation	1996-Present	1951-1991
Elevation (m)	1134	1170
Average Apr 1 SWE (mm)	1500	842
Estimated MAP (ClimateBC)	3420	5040

April-June Runoff vs. Jump April 1st SWE

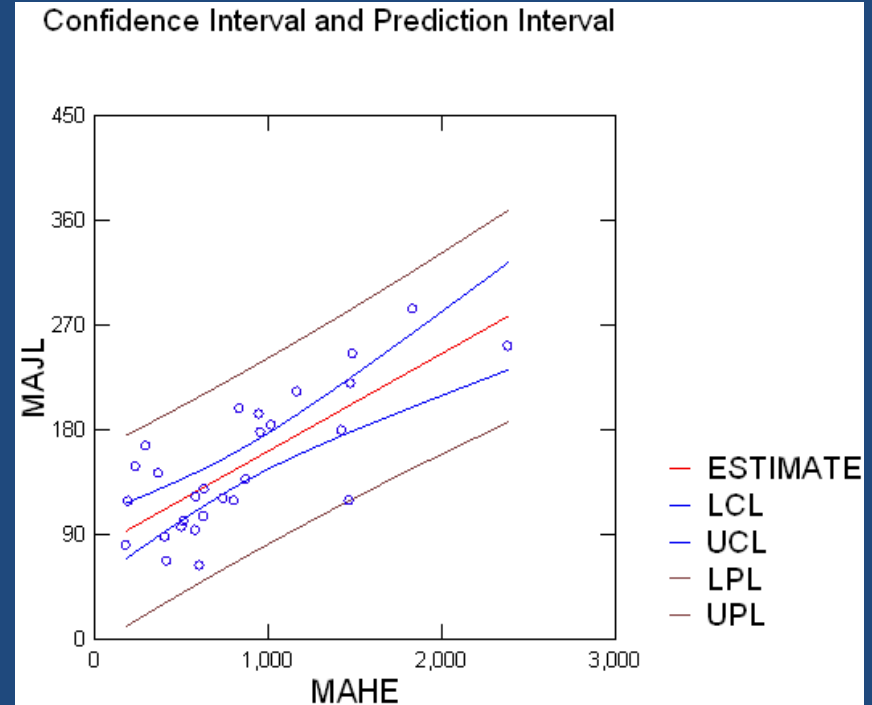
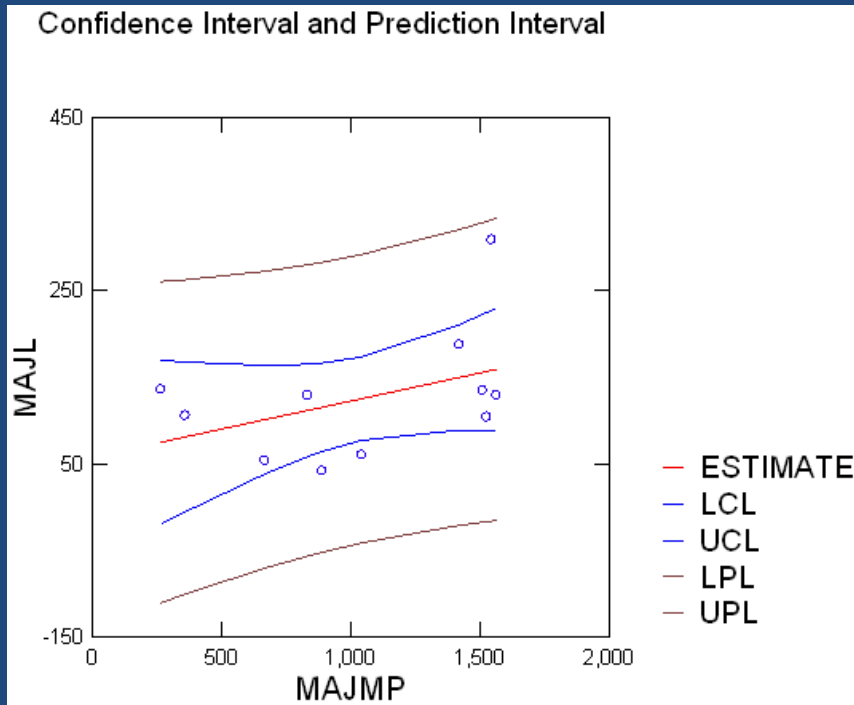


April-June Runoff vs. Heather April 1st SWE



May-July Runoff vs. Jump May 1st SWE

May-July Runoff vs. Heather May 1st SWE



Benefits and Challenges

- Jump Creek ASP is very limited for seasonal forecasting
- Improved seasonal correlations with historic Heather Mountain site
- The very nature of the hydrology on Vancouver Island (rain-dominated systems) will limit the usefulness of any seasonal forecast (forecast skill very limited beyond June/July)
- Highly dependent on rainfall amounts at all times of year (which is inherently difficult to predict)



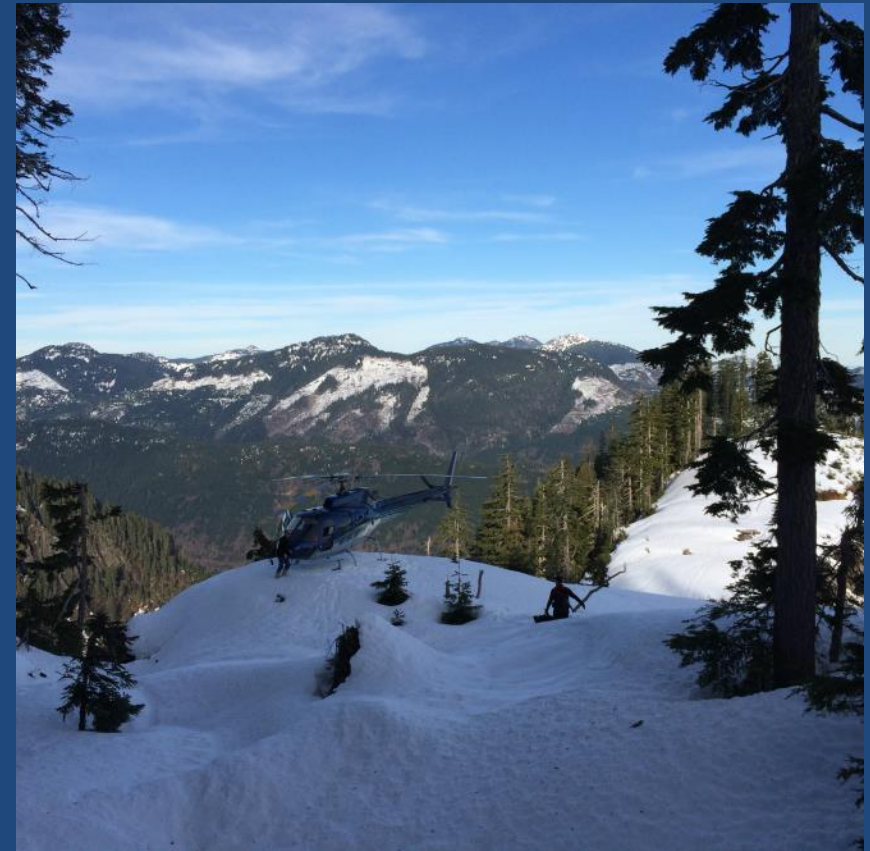
Benefits and Challenges



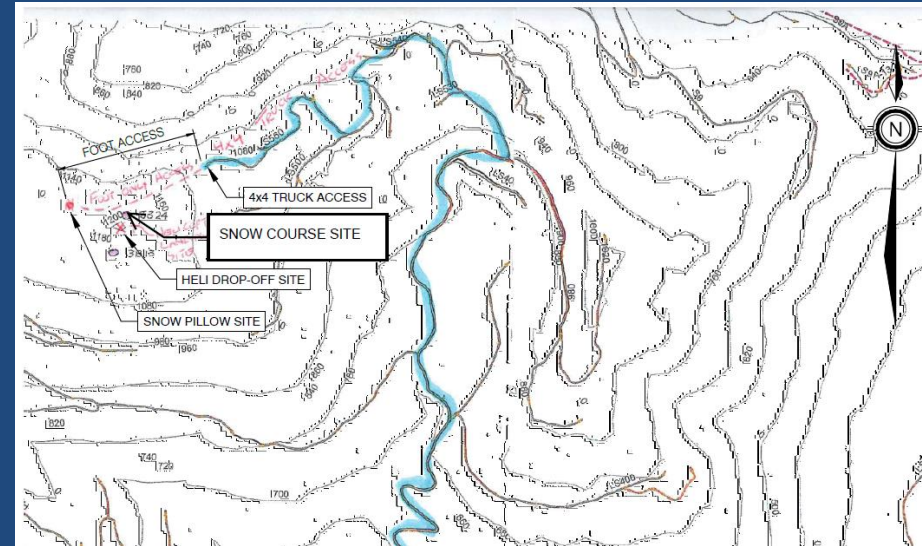
- An ASP site provides real-time data that can be useful for flood forecasting
 - Improved spatial coverage of precipitation
 - Monitor rain-on-snow and snowmelt during storm events
- Monitor spring melt
- Uncertain impact of new information over Jump Creek ASP

Heather Mountain Snow Pillow

- Funding and partnership between Regional (Nanaimo) FLNRO and Cowichan Valley Regional District
- Contracted Kerr Wood Leidal to install
- MOE snow program to maintain and operate



- Site located on Heather Mountain
 - 1190m elevation
 - 1.5 km below peak of Heather Mountain (sub-alpine)
 - Located near historic manual snow survey location



- Constructed in February-March 2015
 - Some weather challenges (snow)



- Snow pillow
- Temperature Sensor
- Total Precipitation
- Snow Depth
- Instrument House
- Transmission Antenna



ASP Operations 2015-16

- Snow depth sensor slightly erratic (tree interference?)
- Snow Pillow readings high (correlation with manual calibration measurement)
- Temperature – good
- Precipitation – good



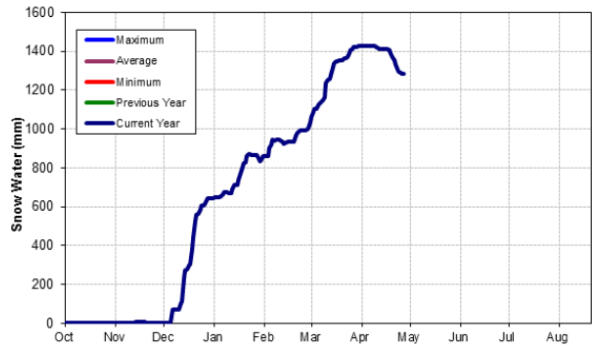
Automated Snow Pillow Real-Time Data

3B24P - HEATHER MOUNTAIN UPPER

Drainage:	Vancouver Island	Owner:	Ministry of Environment
Latitude:	48o 57'	Year Established:	2015
Longitude:	124o 33'	Variables:	Air temperature, snow water equivalent, and snow depth
Elevation:	1,190 m		

Note: Reported snow water equivalent is incorrect (too high). Station is scheduled for maintenance at end of season

Download last 7 days of hourly real-time data*: [Click here](#)
 Download daily archive data: [Click here](#)

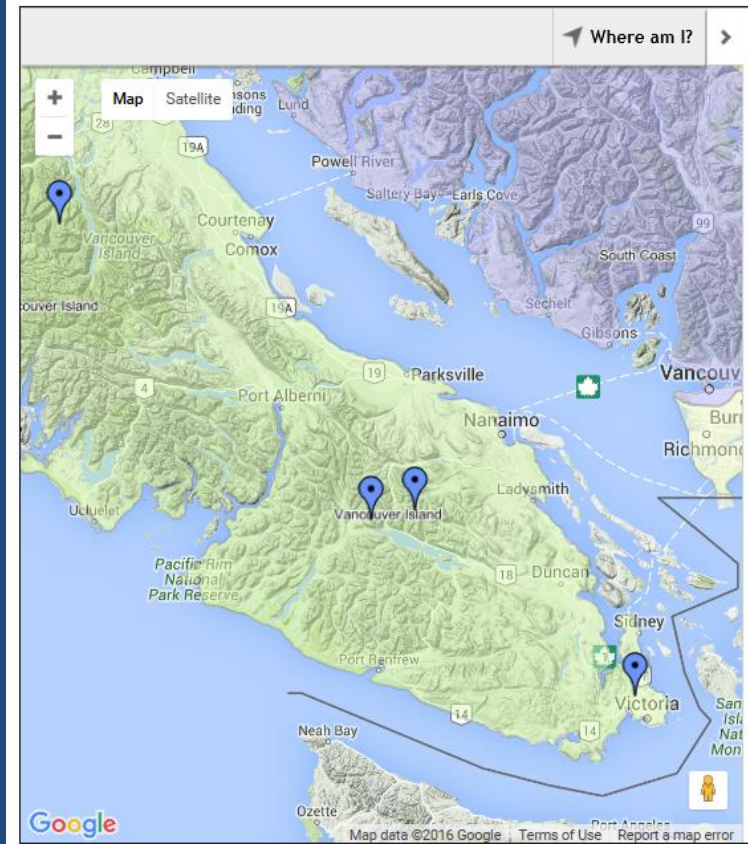


Current to noon 2016-04-26
Updated 2016-04-27 10:42:16 AM

Disclaimer

Automated Snow Pillow (ASP) Data

Snow Survey Basin Areas

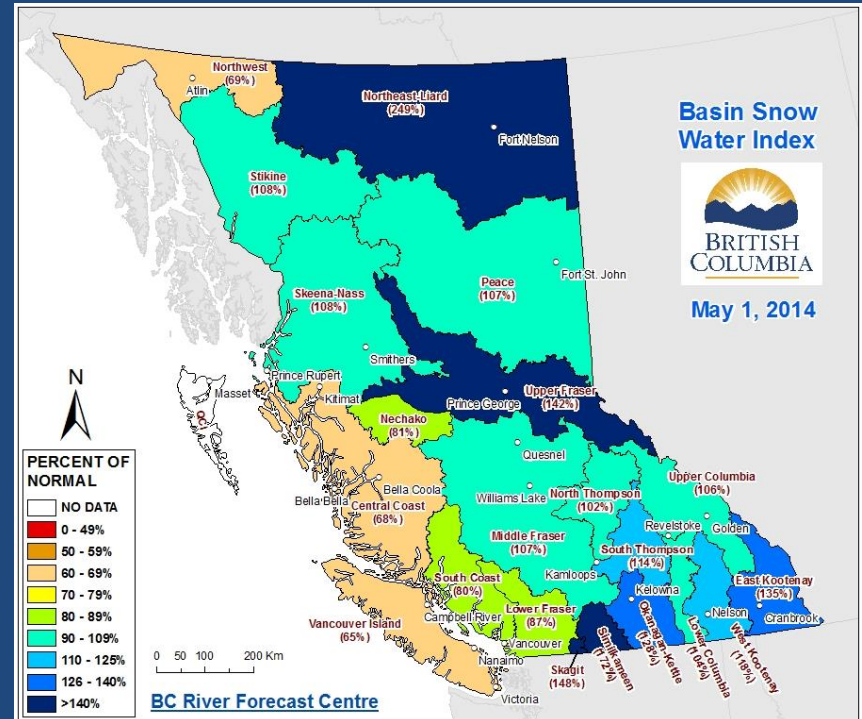
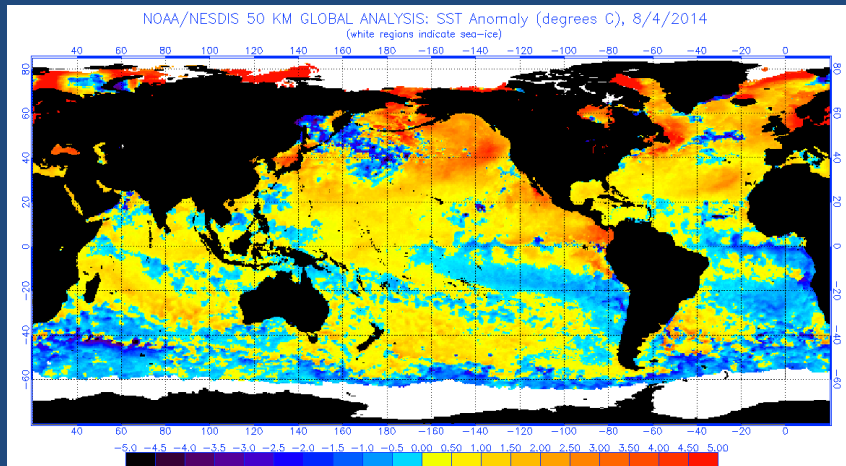


http://bcRFC.env.gov.bc.ca/data/asp/realtime/asp_pages/asp_3B24P.html

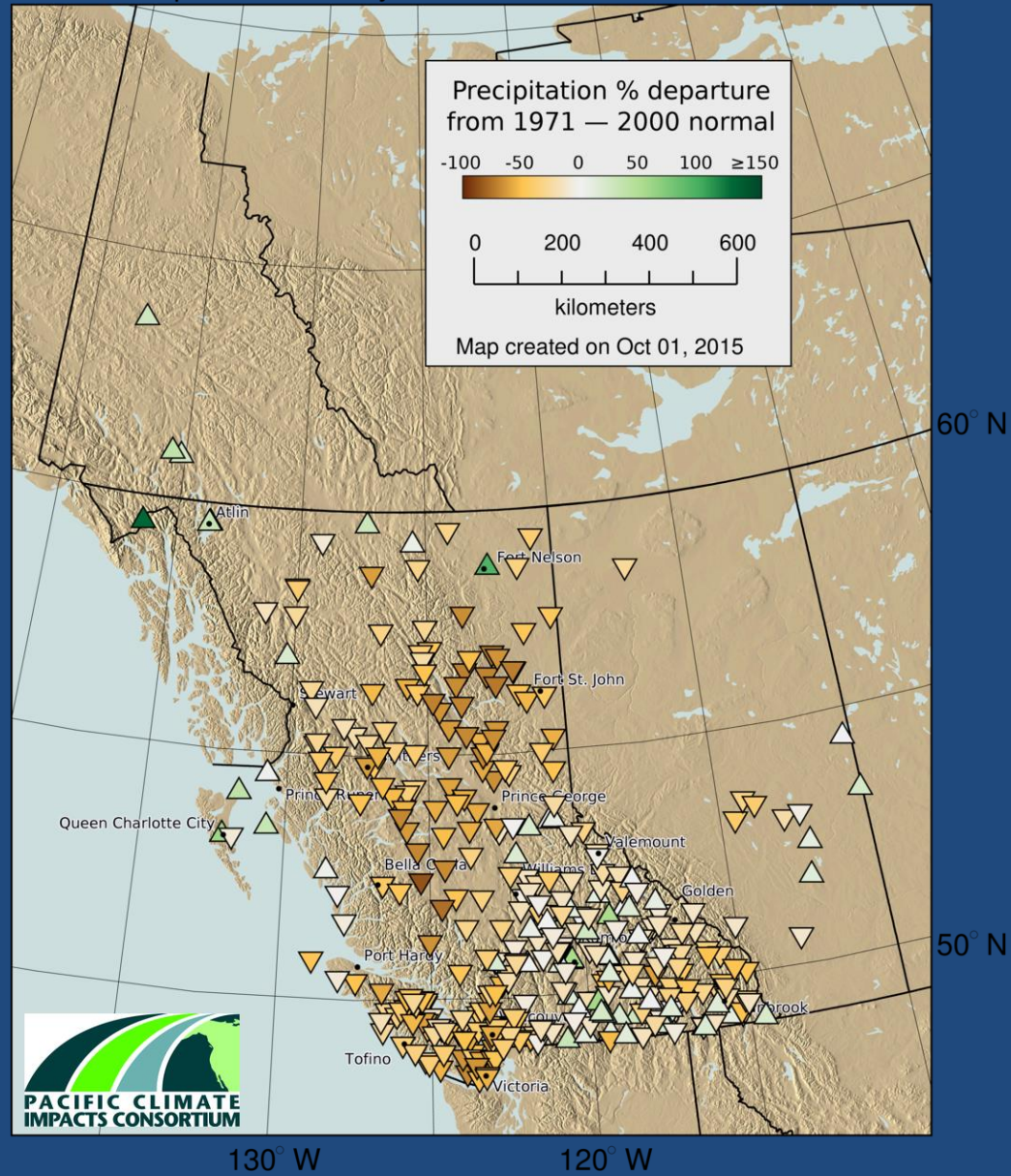
CASE STUDIES



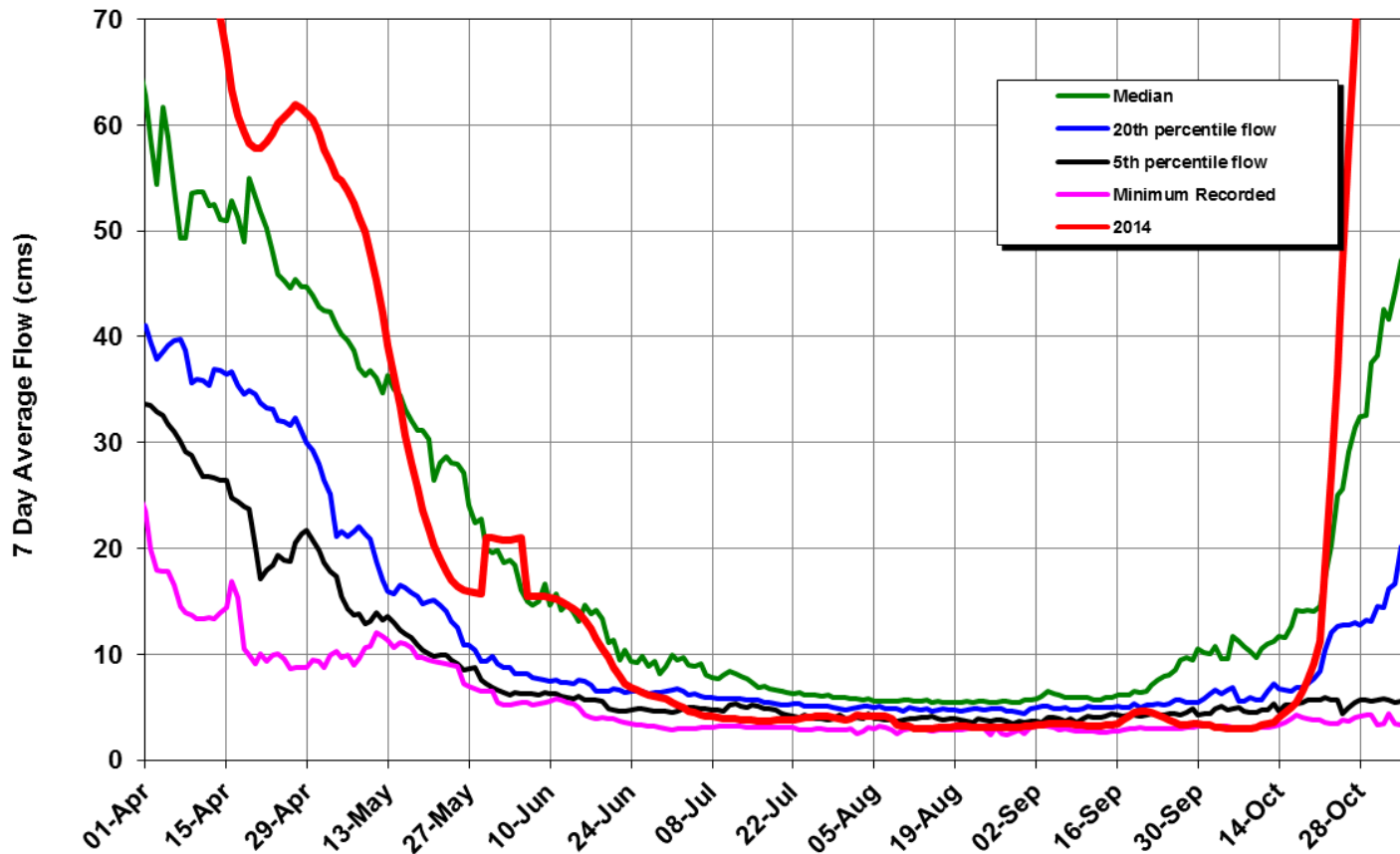
Drought 2014



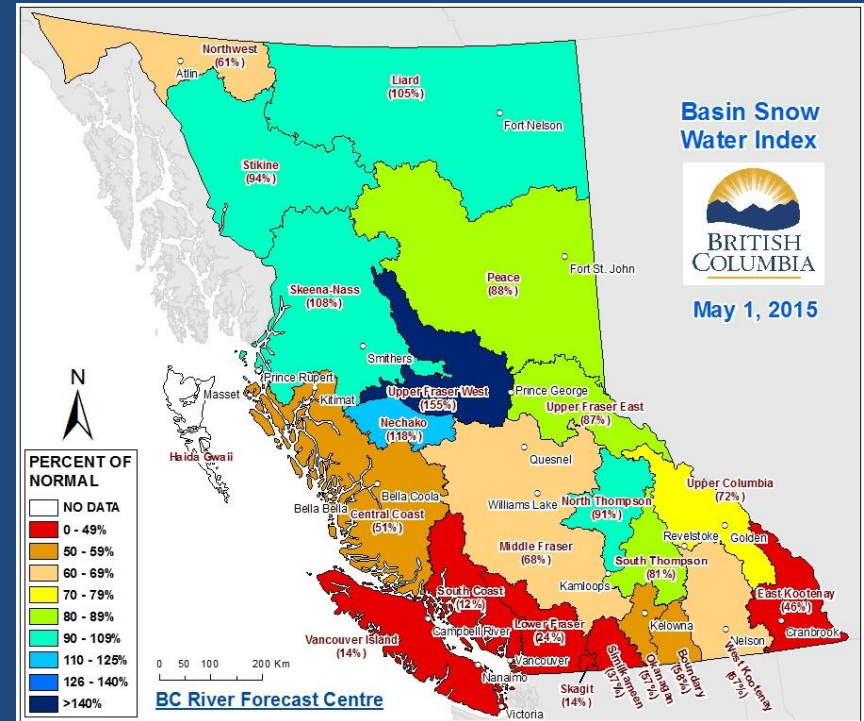
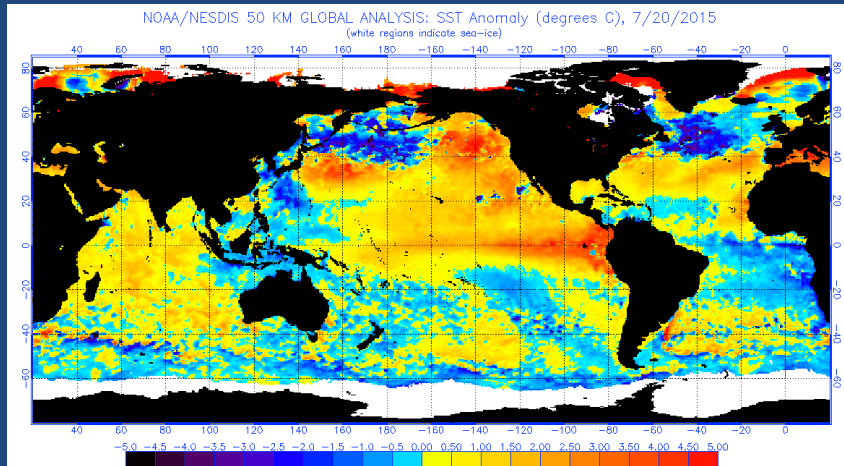
Mean Precipitation Anomaly for JJA, 2014



08HA011 - Cowichan River near Duncan
Area: 826 km²; Years 1960 to 2010



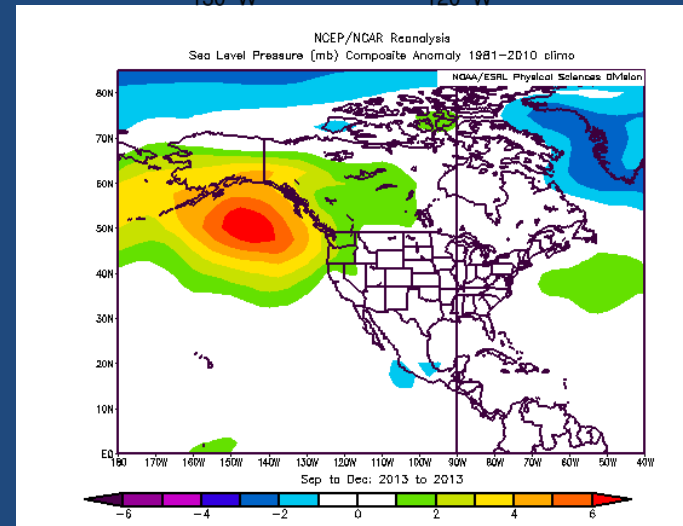
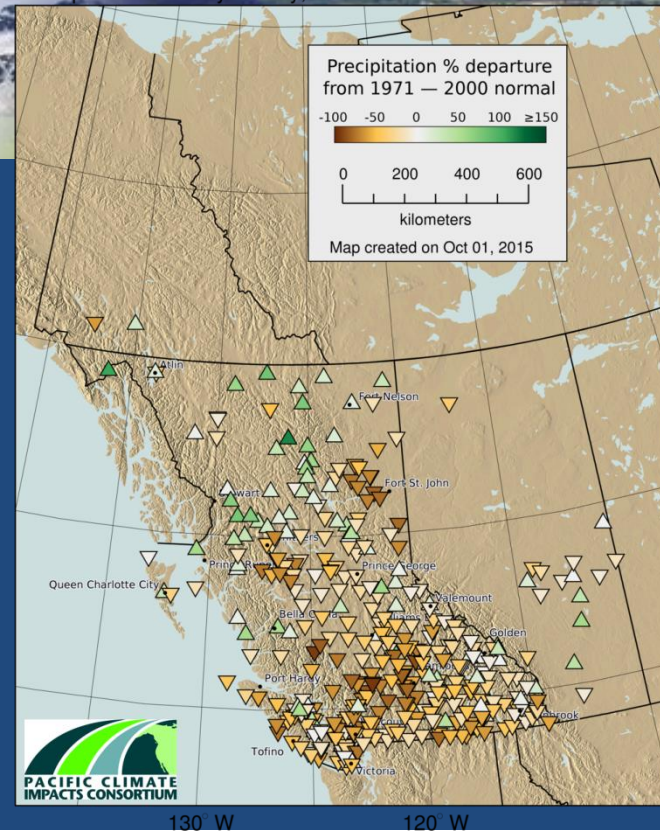
Drought 2015



Drought 2015

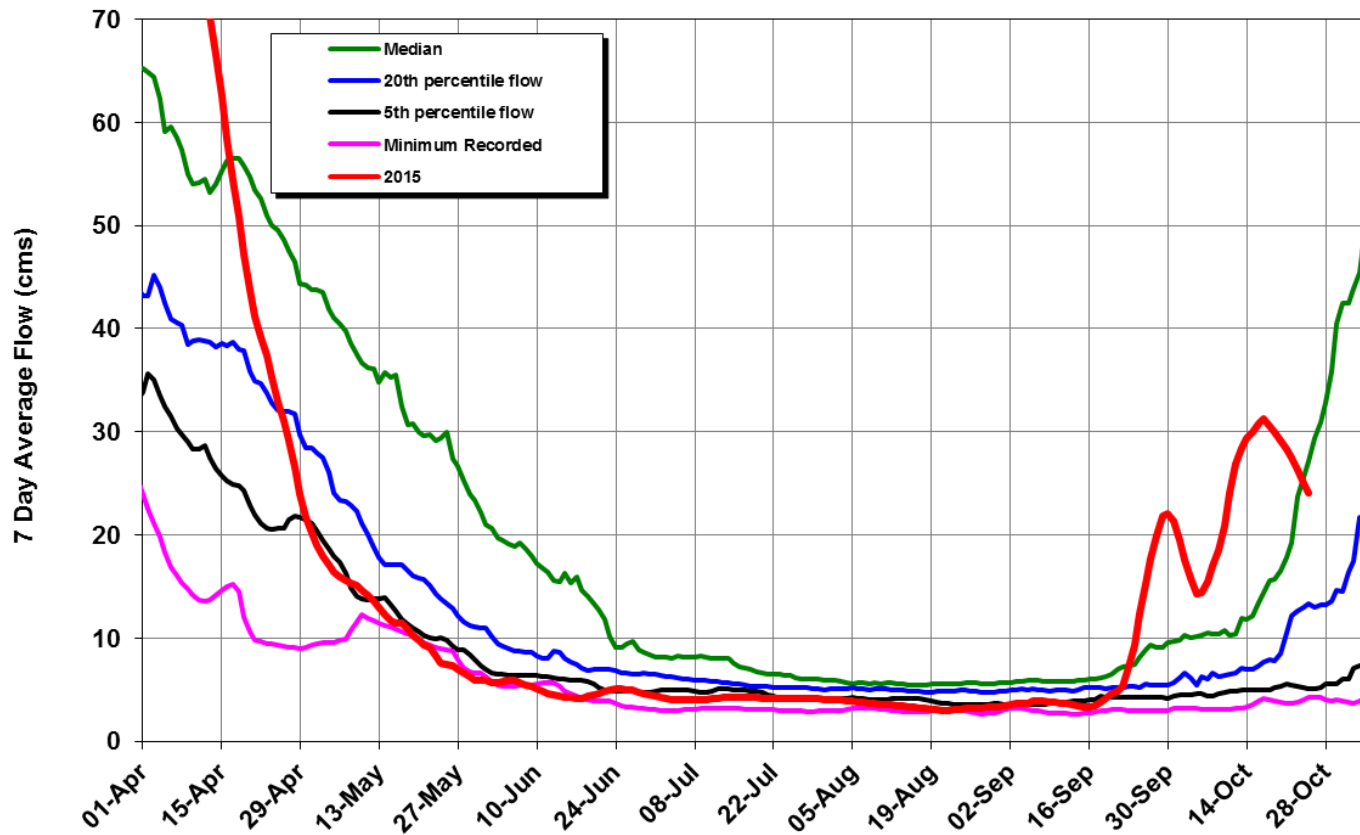
- The “Blob” – extremely warm water off BC coast
- weak El Niño
- Led to persistent warm weather and dry weather
- Essentially no winter snow pack on Vancouver Island and limited precipitation later in the year

Precipitation Anomaly for July, 2015



08HA011 - Cowichan River near Duncan

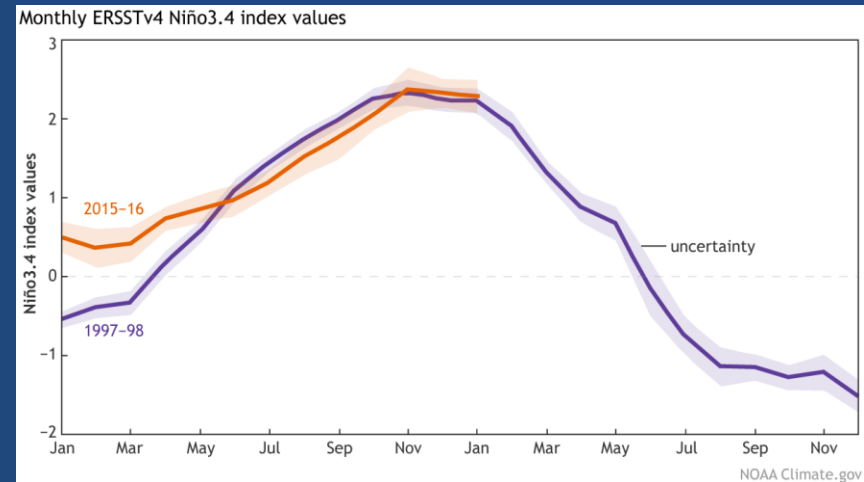
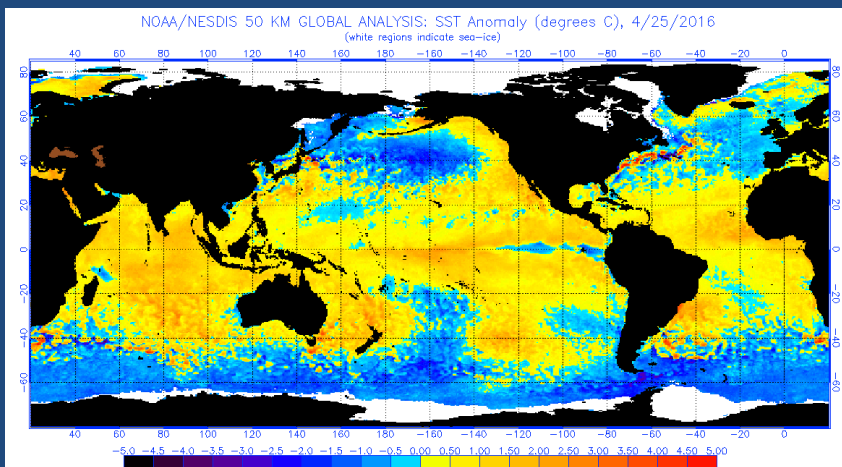
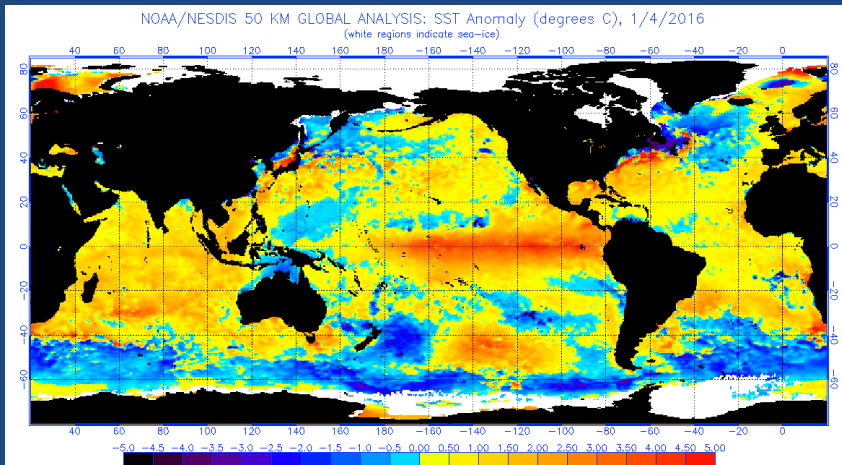
Area: 826 km²; Years 1960 to 2012



Outlook 2016

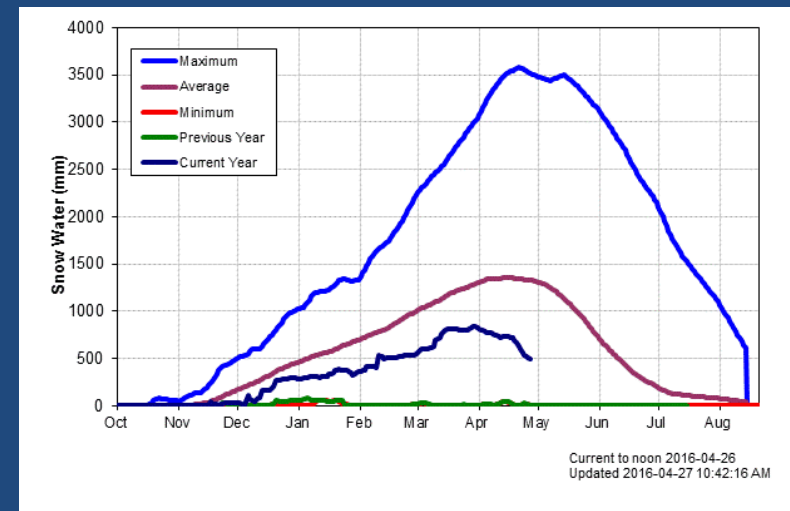
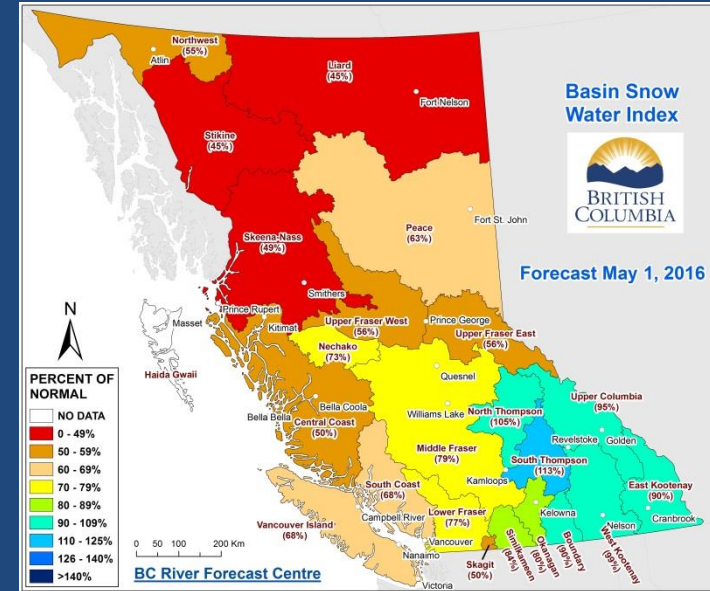


Outlook 2016

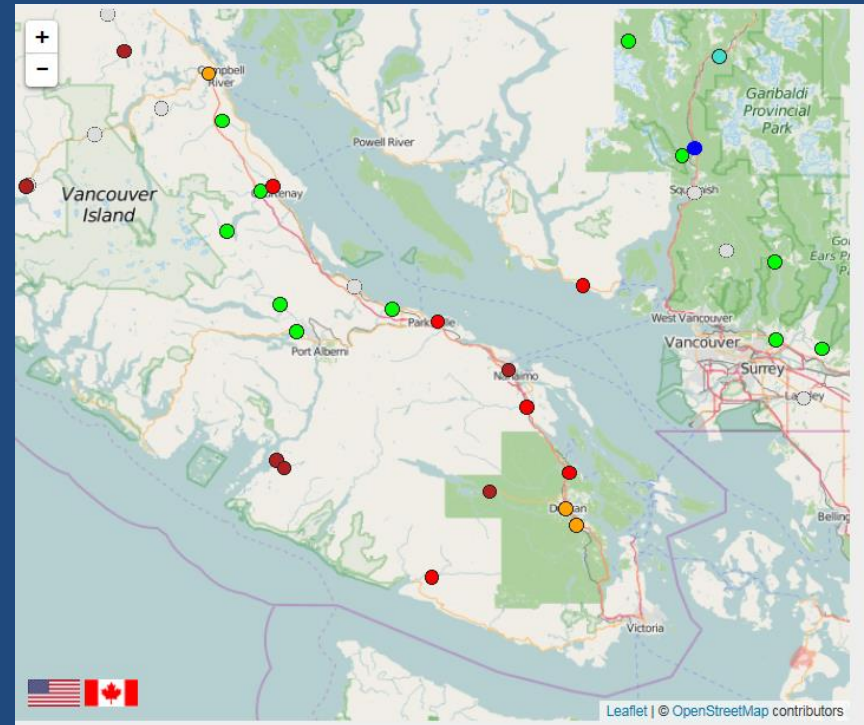
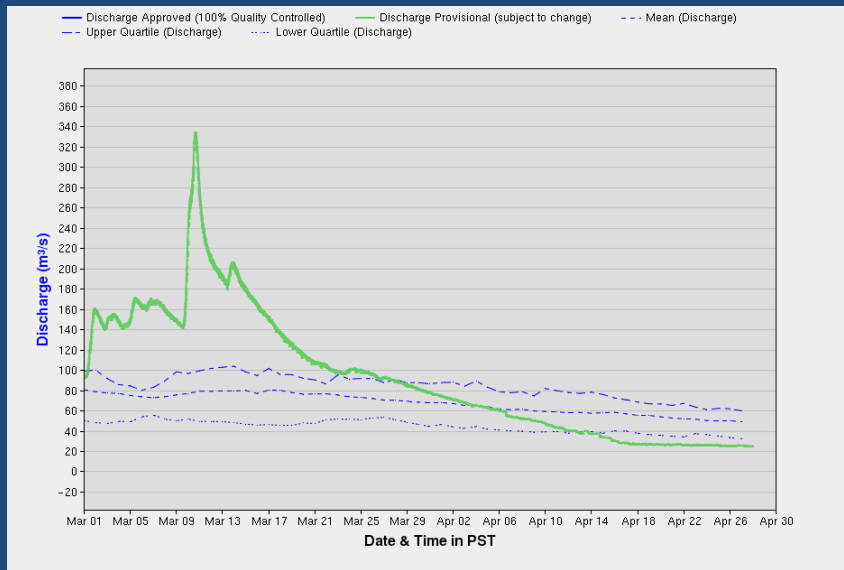


Outlook 2016

- Rapid melt (4-6 weeks ahead of normal)
- Certainly put pressure on snow influence into July and beyond
- Weather still critical
 - Ocean patterns not similar to last 2 years
 - Likely warmer
 - Precipitation uncertain



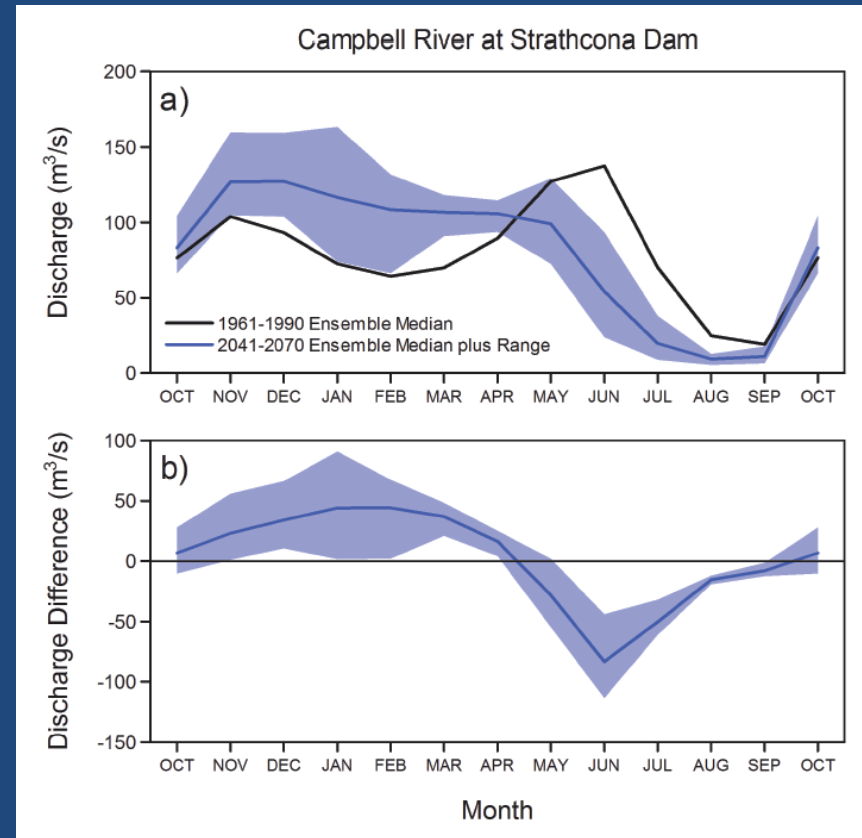
Outlook 2016



COWICHAN RIVER NEAR DUNCAN

Climate Change

- Warmer temperatures
 - Winter and Summer
- Decreased snowpack
- Increased winter flows (melt and precipitation)
- Shift of snow melt to earlier in the spring
 - Trend towards marginal snow influence
- Decreased summer flows
- 2014, 2015, 2016 all examples of what is expected to happen more frequently
 - Future extremes beyond these examples



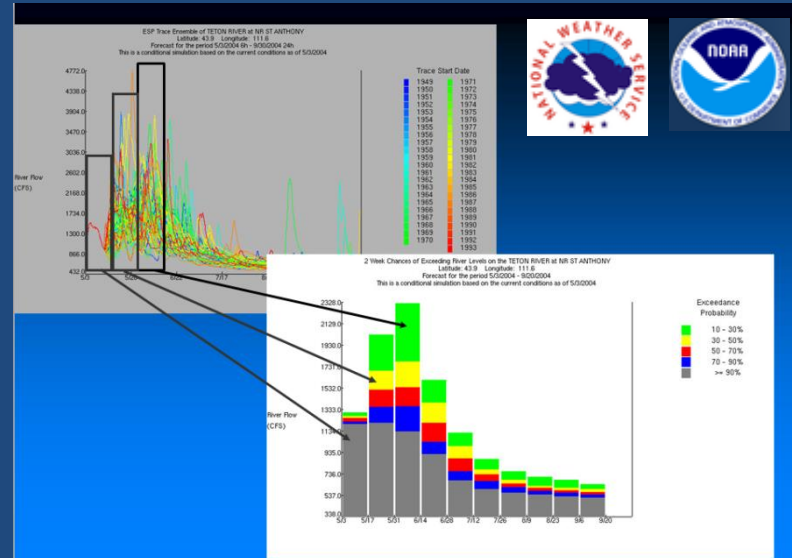
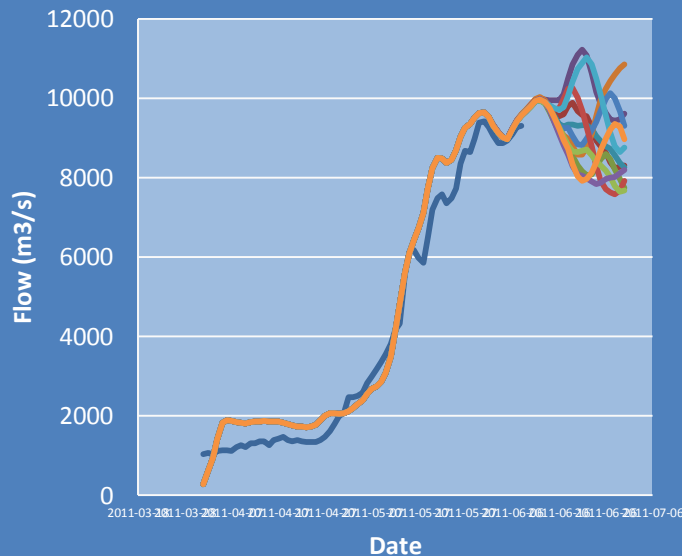
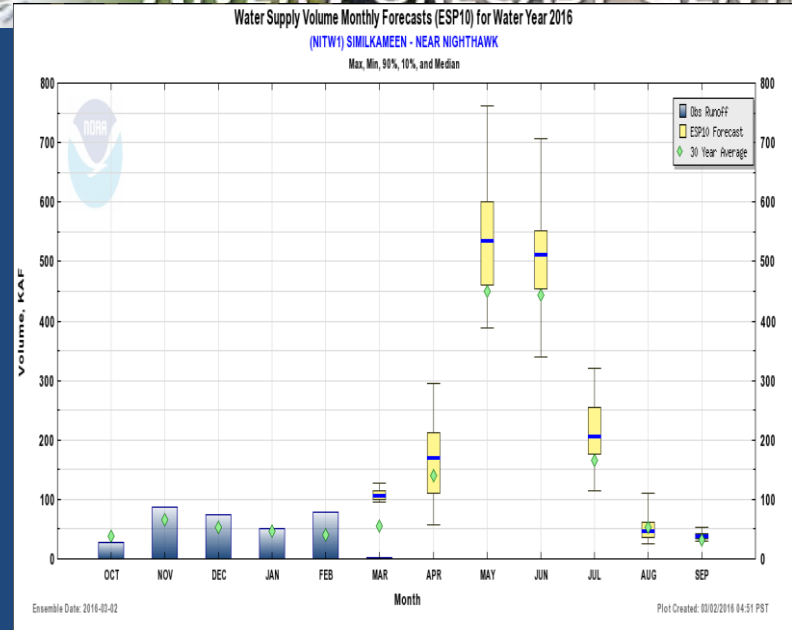
Future of the Heather Mountain ASP?

- Develop historic record
 - Tie in historic Heather Mountain manual measurements
- Discover relationships between snowpack and flow
- Calibrate analysis tools to new data
 - Seasonal flow
 - Real-time forecasting (eg Flood)
- Develop hydrologic models which utilize real-time data

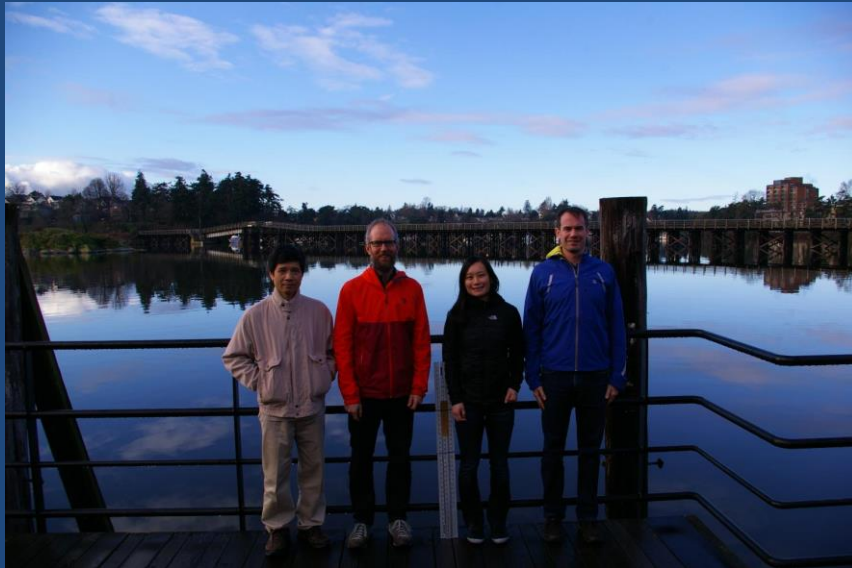


Ensemble Streamflow Prediction

- Force model with larger time-series set (eg historic or synthetic weather)
- Run “What-if” Scenarios (extreme weather, El Nino years etc)
- Can examine possible scenario outcomes or probabilistic peak flow and volume runoff analysis



THANKS!- QUESTIONS?



<http://bcrfc.env.gov.bc.ca/index.htm>