Department of Water Resources:
Statewide Monitoring Network Section

Hydrology Data Acquisition System (HyDAS)

About Me

Bryan Prestel

B.S. Electrical and Electronic Engineering (EEE)

Emphasis: Analog and Digital Controls

United States Navy Data Acquisition (DoD) - 4.5 years

Department of Water Resources – 3 years

Outline

- Intro and Mission
- Legacy Units
- Lessons learned from Legacy Units and Asset/Data management
- Calibration
- New Design
- Software
- Data Users

Words and Acronyms

RPU = Remote Processing Unit

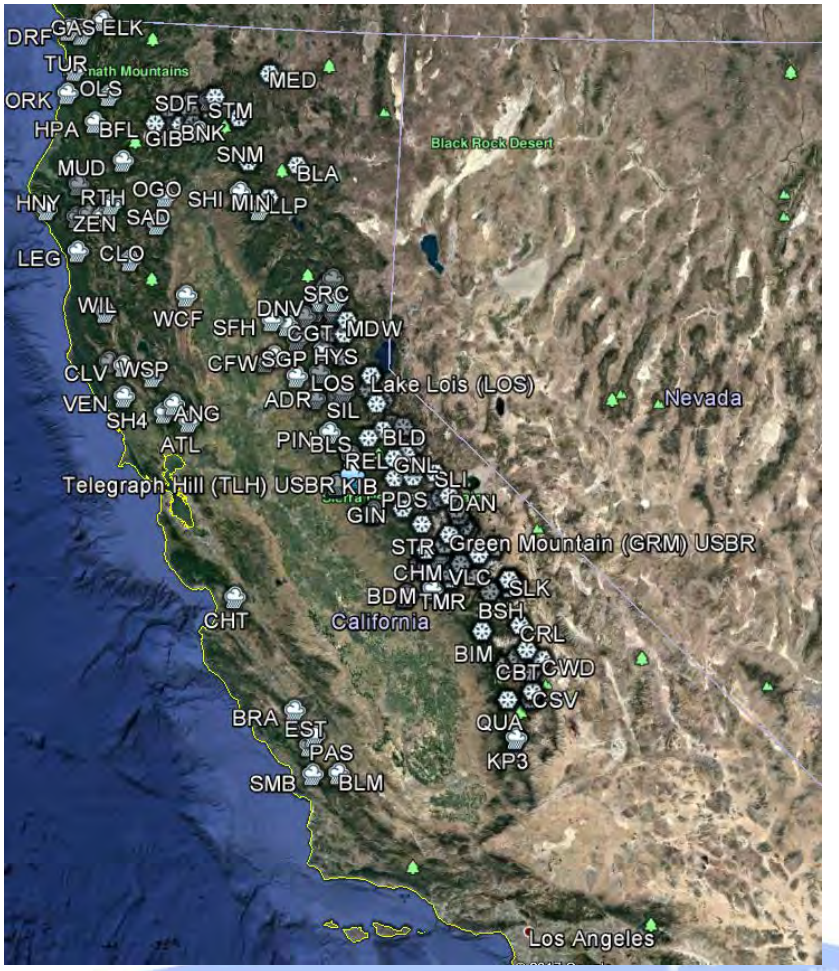
CCSS = California Cooperative Snow Surveys – State run program to measure snow pack information with California state cooperators.

SMN = Statewide Monitoring Network – Section under the Hydrology Branch in the Division of Flood Management at California Department of Water Resources

HyDAS = Hydrology Data Acquisition System

Statewide Monitoring Network

- Responsible for operation, maintenance, and calibration of 139 real-time remote Hydrology Data Acquisition Systems (HyDAS)
- Sierra Nevada, North Coast, San Francisco Bay Area, and Central Coast.



Primary Use of Stations

DWR Mission - To manage the water resources of California in cooperation with other agencies, to benefit the State's people, and to protect, restore, and enhance the natural and human environments.

Division of Flood Management HyDAS Responsibilities – providing reliable, accurate data to support flood emergency decisions.

Legacy Units
Vaisala Handar 555 RPU

Vaisala Handar 555

Legacy Unit continued

- **<u>Handar 555 Specs</u>**
- Power:12V
- Inputs
  - 16 analog inputs
  - 1 frequency input
  - One pulse counter
  - Two Quadrature Encoders
  - 8 digital inputs
  - One SDI 12 input
- Outputs
  - 9 digital Outputs
  - Two switch 12V outputs
  - +5v ref output
- Clock drift 15sec per month
- 128 kb RAM
- 1 Mbyte Non-volatile data memory
- Modem/RF Output

Legacy Communications
Geostationary Operational Environmental Satellite (GOES)

- One Way Satellite communication is the only reliable way to transmit data in steep, rugged, and remote alpine.
- 2015 completed Legacy radio upgrade from 100 Baud to 300 Baud

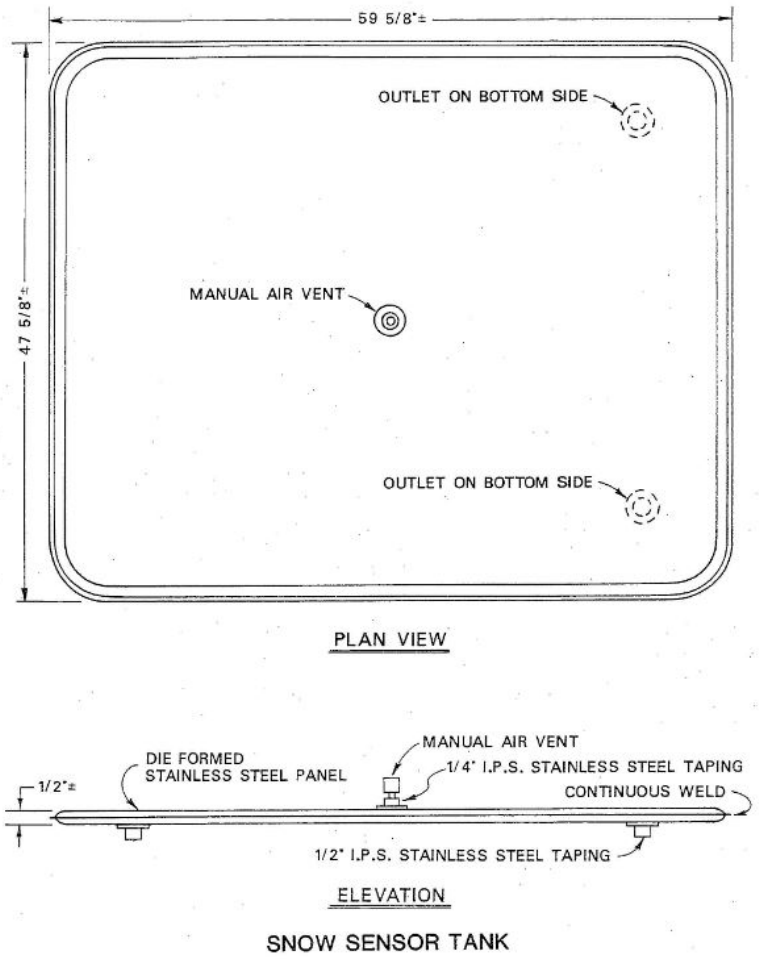
Legacy Unit Continued

- DWR's Division of Flood Management installed many in early 2000's from Army Corp surplus
- Last software support was for Windows XP.
- Pre-Set Analog in values, not programmable.
- No Standard Pin-Out
- Limited documentation of Sensor programming and installation
- Communications Only one way.

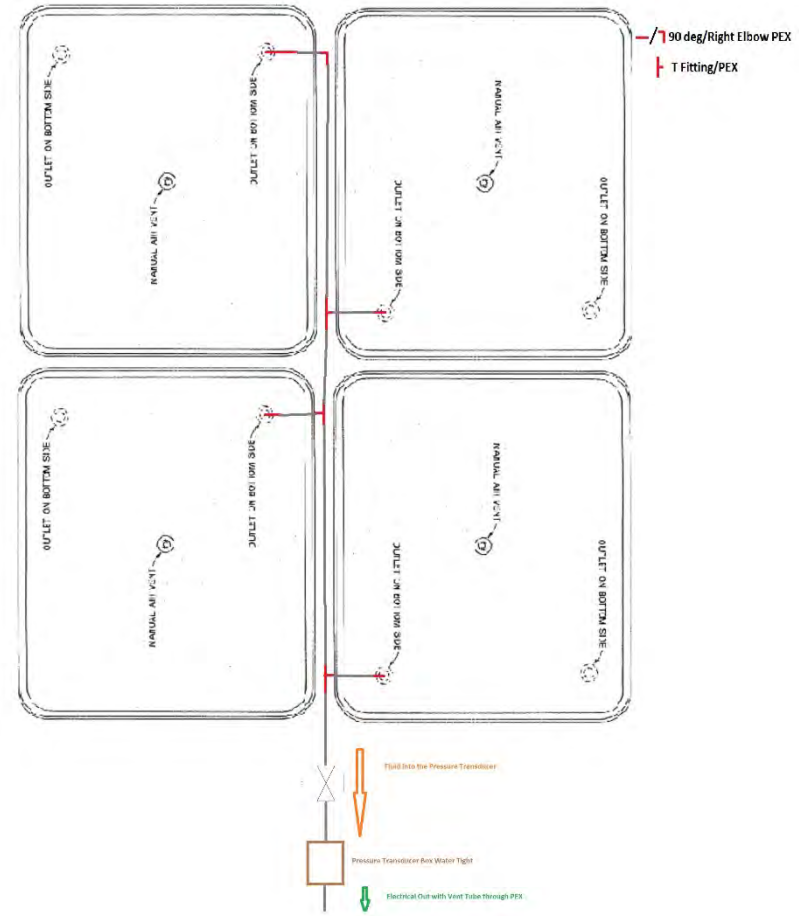
Mission Critical data:

Snow Water Content

Snow Pillow



Snow Pillow Installation
4 pillow layout



Snow Pillow Installation

Common Legacy Station Failures across the State

Power Failures

- Batteries died
- DCP stopped transmitting

Snow Pillow Failures

Judd Snow Depth Sensors

Mineral King Sequoia Kings National Park

Farewell Gap (FRW)

Farewell (FRW)

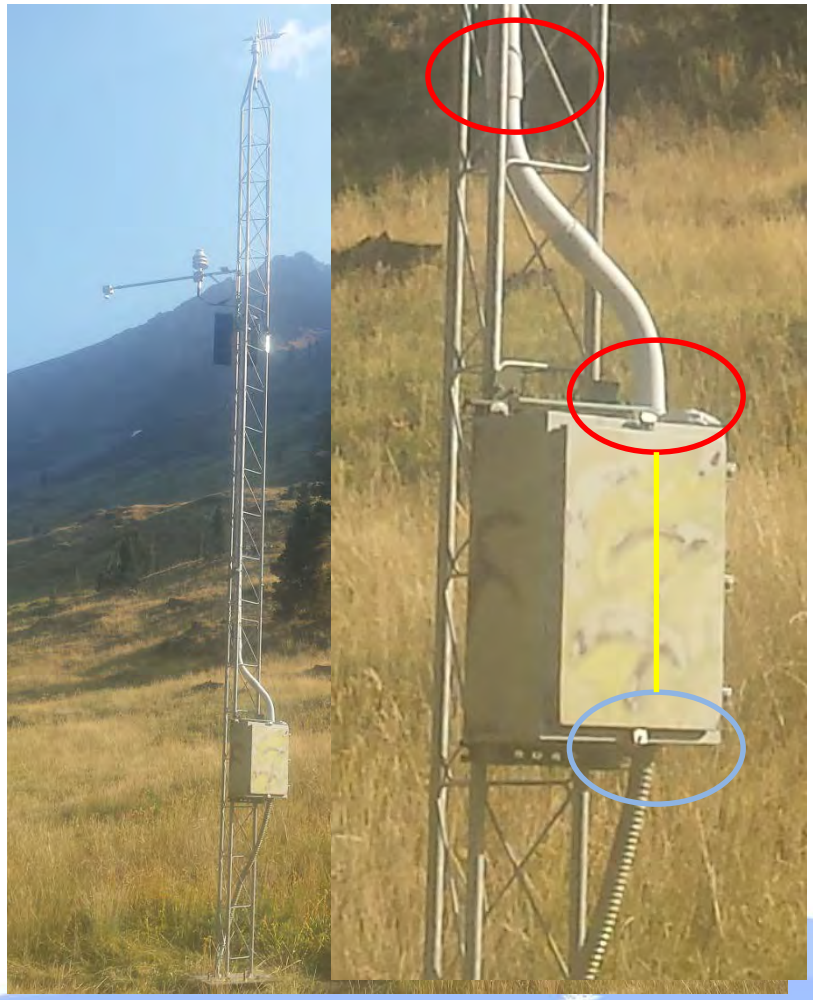
Kaweah Delta Watershed

Failure: PWR Bus Short/Blown Fuse: Complete Station Failure

Root Cause – Water intrusion

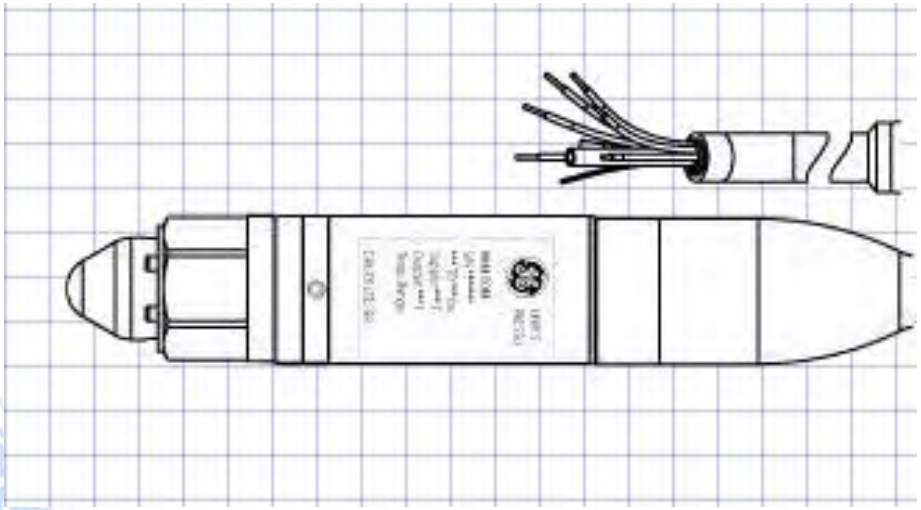
Farewell Gap (FRW) Cont.

How did water intrusion happen?



Solution: The Use of Submersible PT's

- DRUCK UNIK 5000
- 0-5V Analog Out (New Device and Works on Legacy Units)



Farewell Gap (FRW) Continued

The Fix

- Submersible Pressure Transducer in a NEMA 4x Box.

Legacy Current Goals
Year 2016

- Create Fixes to ensure critical mission data for snow pack is in place.
- Install New Pressure Transducers on Legacy Units
- Take out old devices and Calibrate to provide quantitative data to management.
- Start to design full station upgrades.

Important Note

CALIBRATION

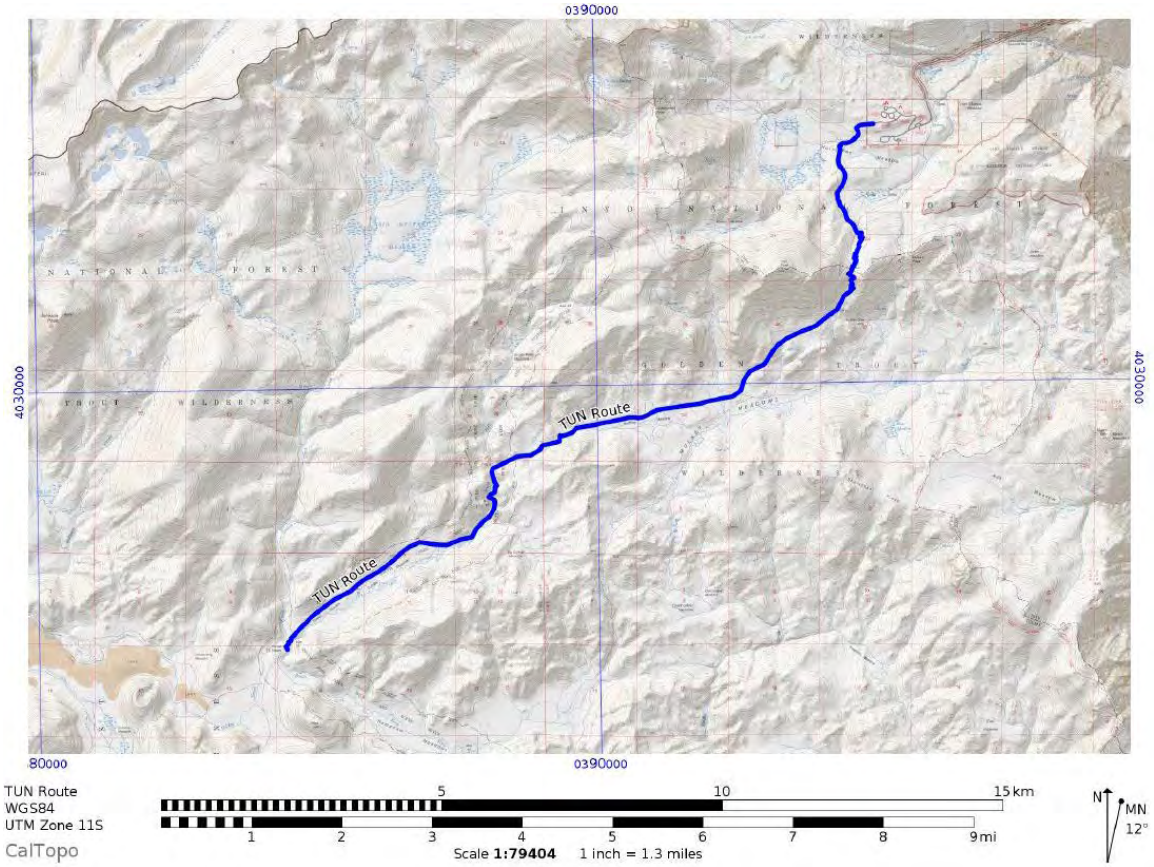
- Legacy Systems: No Calibration Program
- Electronics slowly break down over time
- The break down can change the output values and tolerance of the device.
- Proper calibration will ensure device accuracy, as well as reliability in the field.

Field Stations

(Southern Sierra)

Tunnel Guard Station,

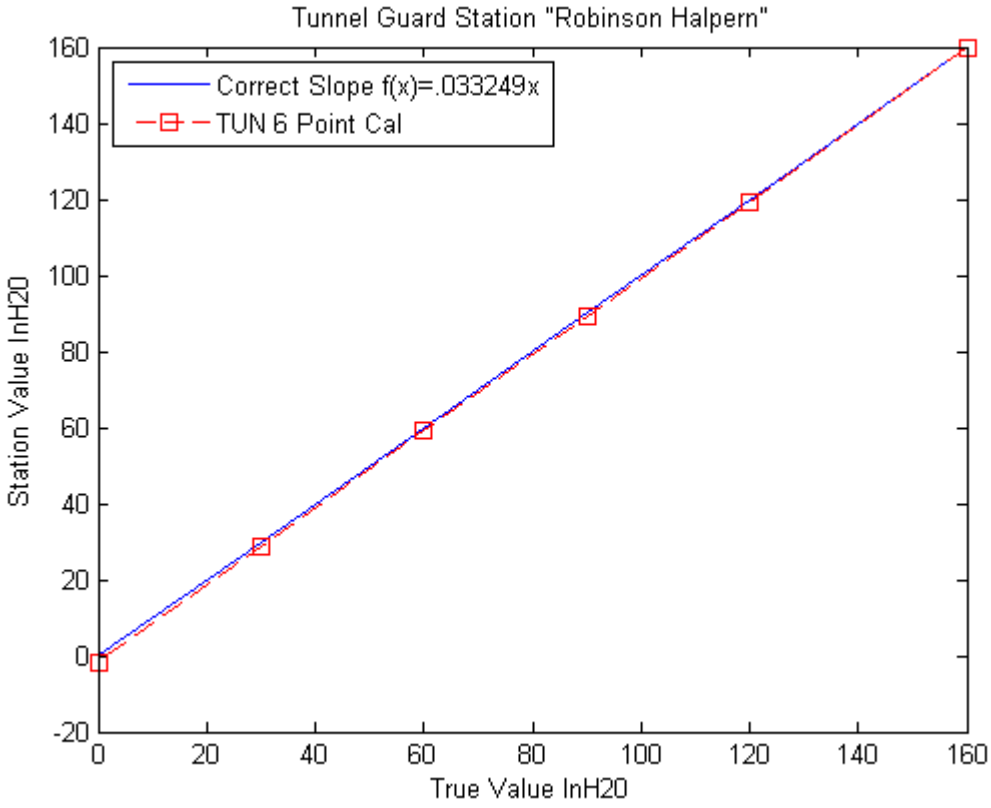
Golden Trout Wilderness, Inyo National Forest



Tunnel Guard Trail

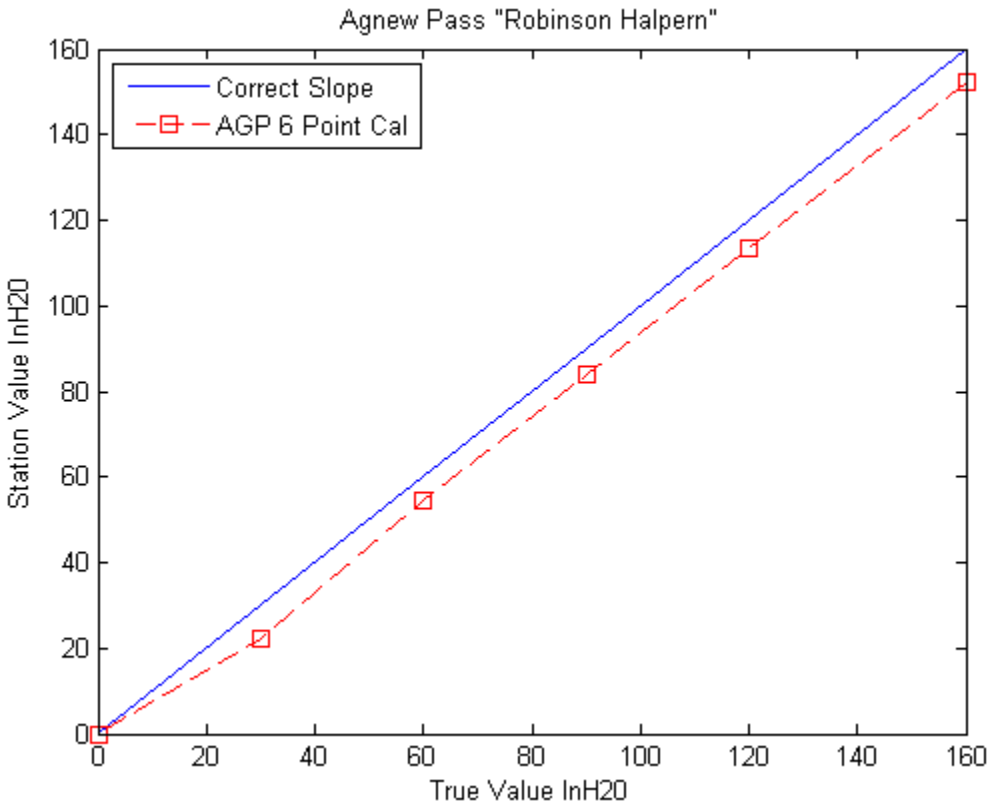
11 Mile One Way Journey

Tunnel Guard



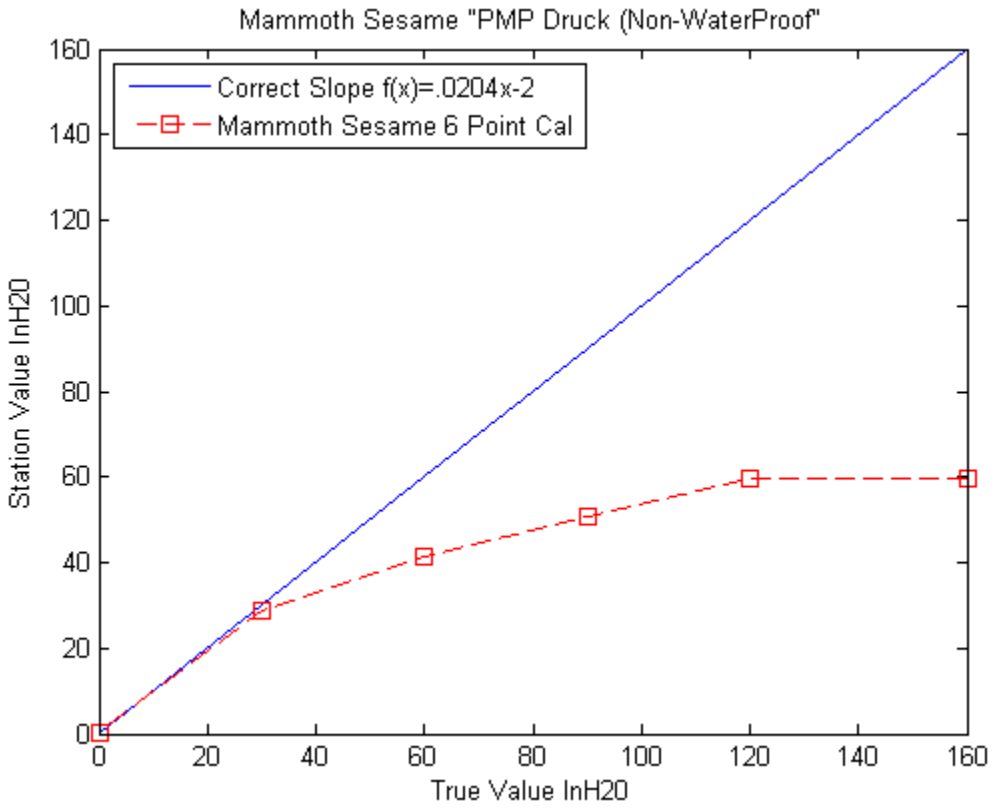
Inches of Water	mVout Measured	Output SWE	Percent Error
0	-50	-1.66	0.00%
30	866	28.79	4.02%
60	1780	59.18	1.36%
90	2685	89.27	0.81%
120	3584	119.17	0.70%
160	4807	159.83	0.11%

Agnew Pass



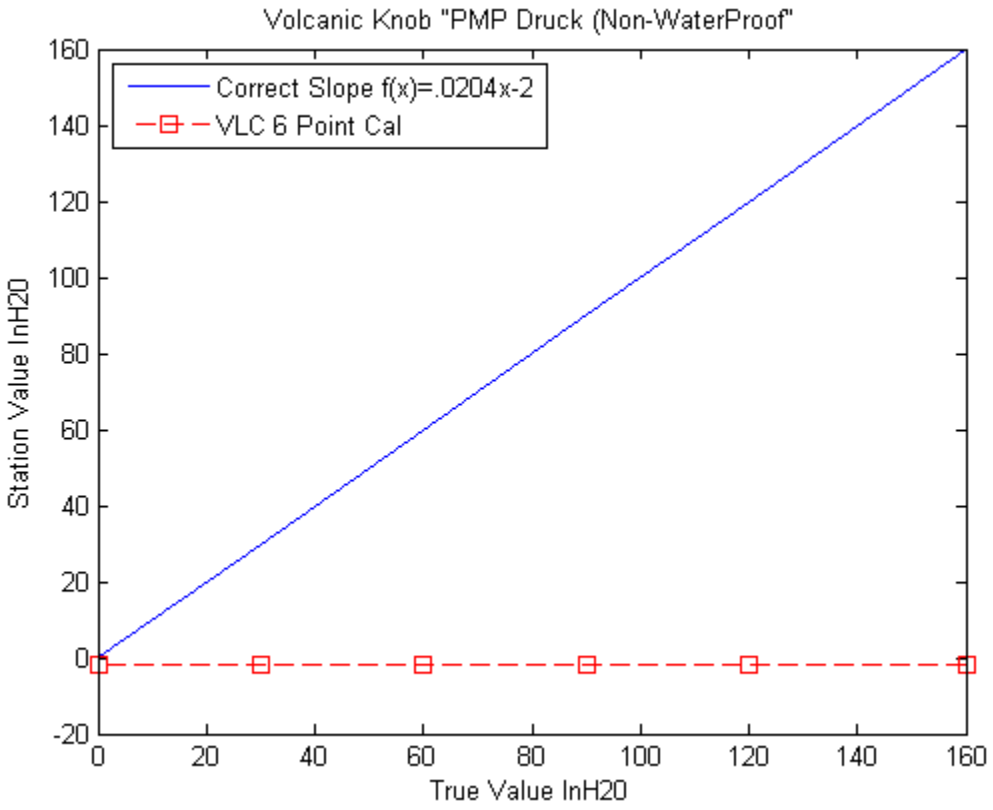
Inches of Water	mVout Measured	Output SWE	Percent Error
0	0	0	0%
30	670	22.28	25.74%
60	1634	54.33	9.45%
90	2529	84.09	6.57%
120	3409	113.35	5.54%
160	4583	152.38	4.76%

Mammoth Mountain Sesame Snow Station



Inches of Water	mVout Measured	Output SWE	Percent Error
0.00	117.00	0.39	**0%**
30.00	1505.00	28.70	4.35%
40.00	2118.00	41.21	3.02%
60.00	2588.00	50.80	15.34%
80.00	3026.00	59.73	25.34%
100.00	3029.00	59.79	40.21%

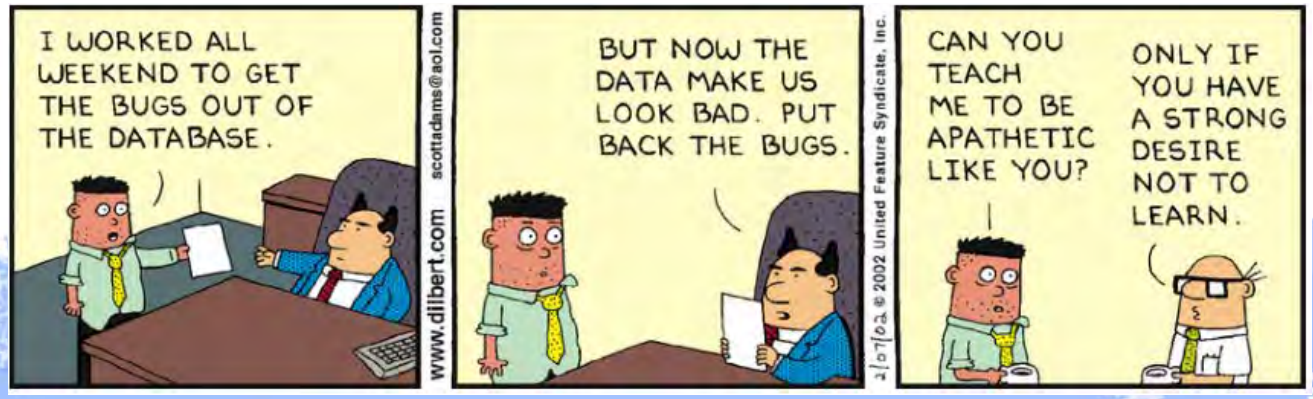
Volcanic Knob



Inches of Water	mVout Measured	Output SWE	Percent Error
0	0	0	**0%**
20	0	0	100%
40	0	0	100%
60	0	0	100%
80	0	0	100%
100	0	0	100%

Priorities and Challenges

- Reliable data
- Degrading network of instruments
- End User misunderstanding of data
- Trusting the data
- Creating a standard configuration between instruments and stations
- Room for growth and improvements



Design Questions

- What is it being used for, what is its intended purpose and function?
  - Research
  - Operations
  - Hydrometeorlogical Modeling
- What are we measuring?
  - What way are we measuring it
    - Understanding what we are measuring, helps us find the best application of measurement.

Design Questions Continued

What Instrument best suites its function?

- Resolution
- Accuracy
- Reliability
- Configuration (Complexity)
    - Set Up
    - Data Configuration
    - Resource/Infrastructure
- Calibration

Balance

- Between Resolution, practical use, and data outages.

Knowledge and Competence are key

Future Expansion

- Develop an open architecture design that allows for current instruments and future technologies for max interoperability.
- Expanding battery bank capabilities to 12V, 24V, and increasing overall power available
- Develop/Test new technology to improve data quality and reduce the need for propylene glycol.

Data Acquisition Basics

Awareness and Knowledge

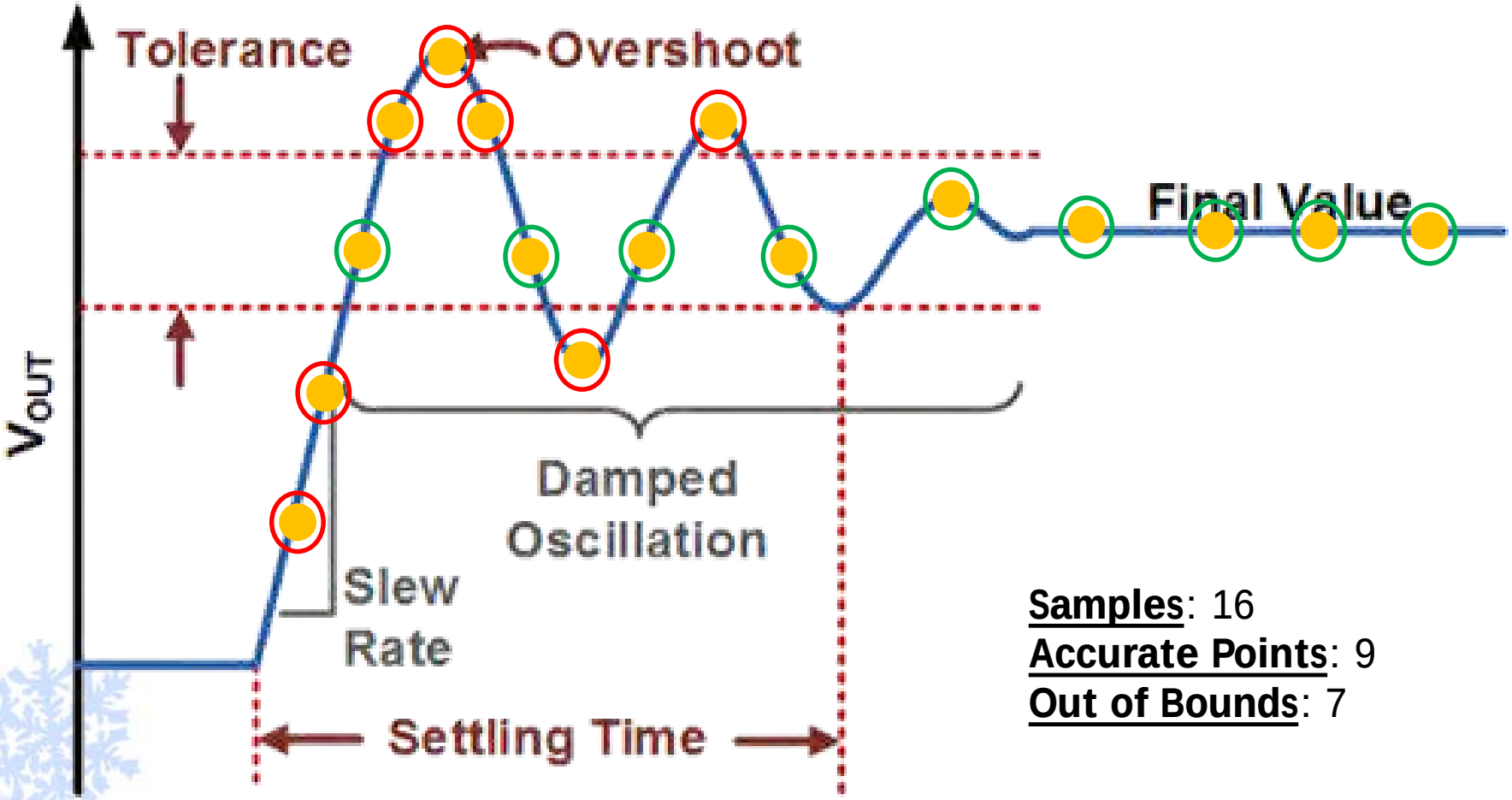
- Double check you are sampling a sensor or instrument after its settling time.
- If not you could be over or under measuring the device.
- Best Practice:
  - wait to sample at **least** twice the settling time to ensure accurate results.

Sensor Sampling

Old vs New Data Sampling

- The time it takes the instrument/sensor/transducer from "Power On" to reach steady state.
  - Steady State – A continuous accurate output within the error margins defined by the datasheet.

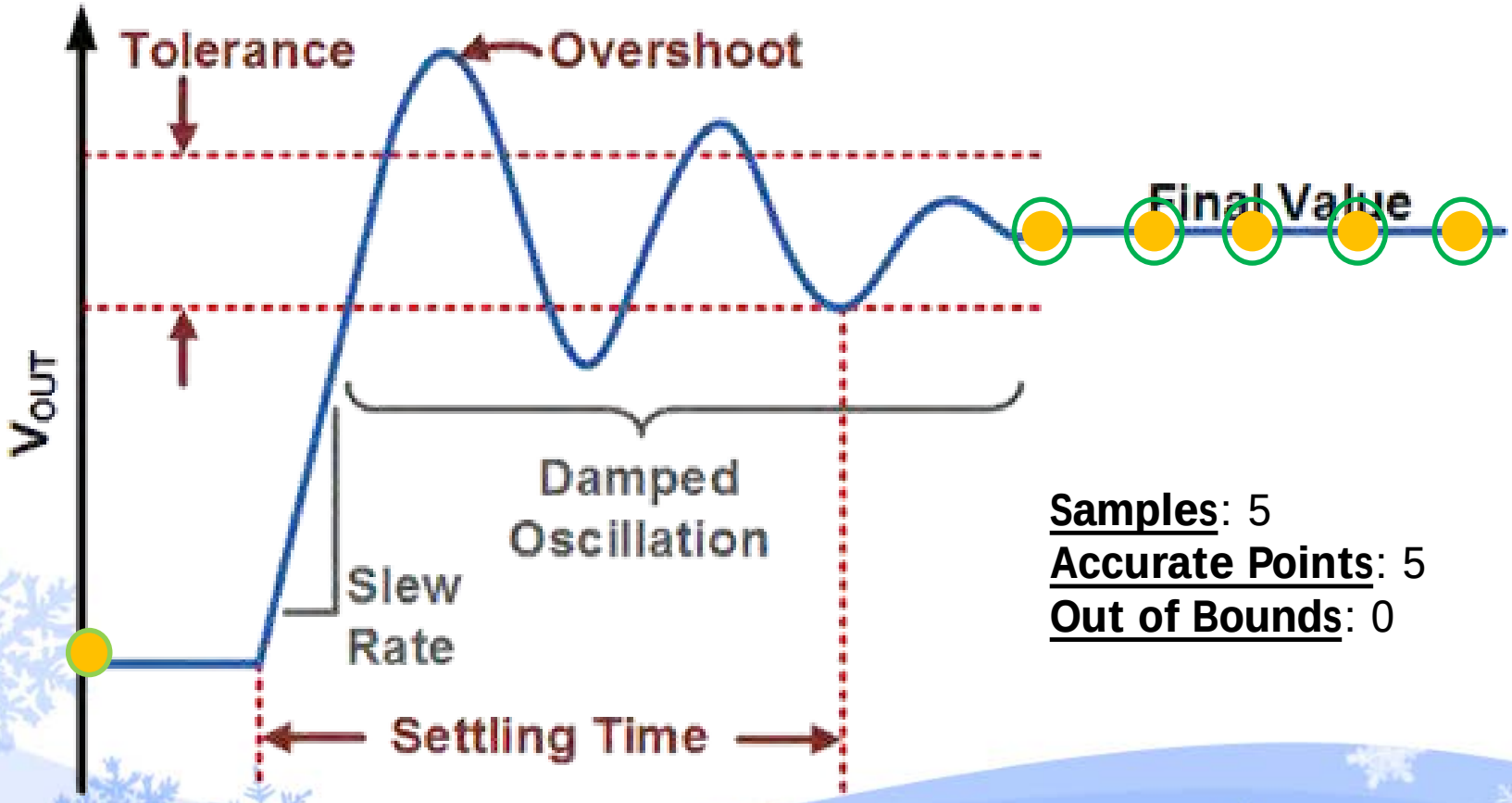
Old Sampling



Samples: 16
Accurate Points: 9
Out of Bounds: 7

Correct Sampling

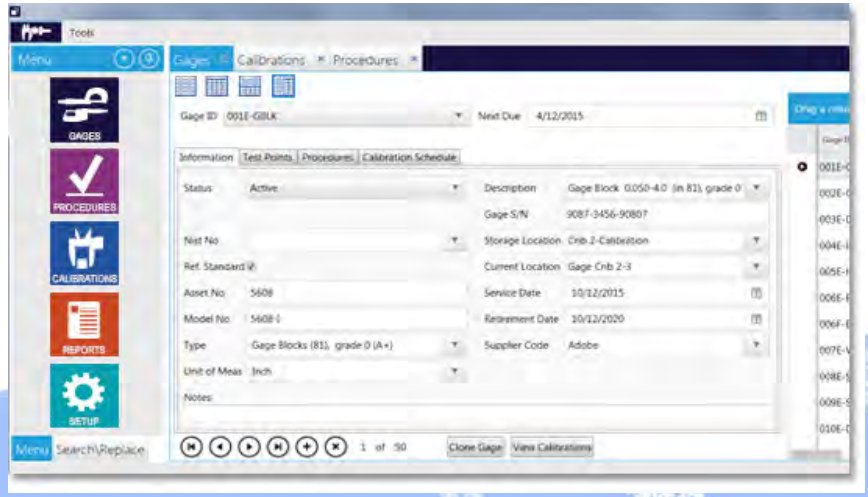
Sampling Method



Samples: 5
Accurate Points: 5
Out of Bounds: 0

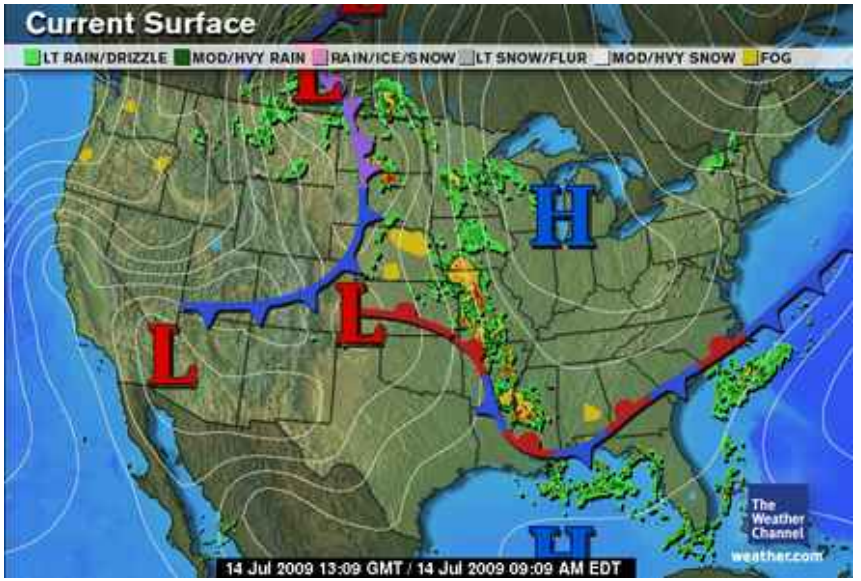
Calibration and Instrument Management

- Creating a calibration cycle that ensures proper instrument management.
- Switching out sensors based on manufactures recommended calibration cycle
- Tracking and managing equipment through GAGE Trak
- Installing Glenn Martin Fold over towers to ensure easy to access instruments and increased safety



Barometric Pressure

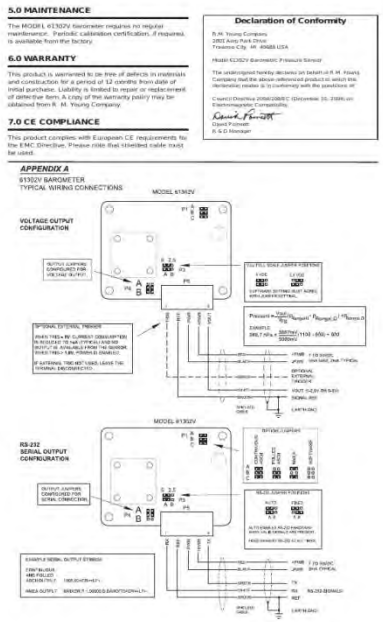
- Pressure Type
  - Station Pressure
  - Sea level Pressure
    - Adjusted for elevation
- Elevation
  - Min Pressure
  - Max Pressure
- Output Parameter
  - Hecto Pascal
  - Millibar
  - InHg



Barometric Pressure Continued

Barometer(Sea Level Pressure): RM Young 61302V

- Output Parameters: Sea Level Pressure (inHg)
- Sample Frequency: 20min



5.0 MAINTENANCE

The MODEL 61302V barometer requires no regular maintenance. Periodic calibration certification, if required, is available from the factory.

6.0 WARRANTY

This product is warranted to be free of defects in materials and construction for a period of 12 months from date of initial purchase. Liability is limited to repair or replacement of defective item. A copy of the warranty policy may be obtained from R. M. Young Company.

7.0 CE COMPLIANCE

This product complies with European CE requirements for the EMC Directive. Please note that shielded cable must be used.

Declaration of Conformity

APPENDIX A

61302V BAROMETER

TYPICAL WIRING CONNECTIONS

MODEL 61302V

VOLTAGE OUTPUT CONFIGURATION

RS-232 SERIAL OUTPUT CONFIGURATION

INSTRUCTIONS

MODEL 61302V

BAROMETRIC PRESSURE SENSOR

CE

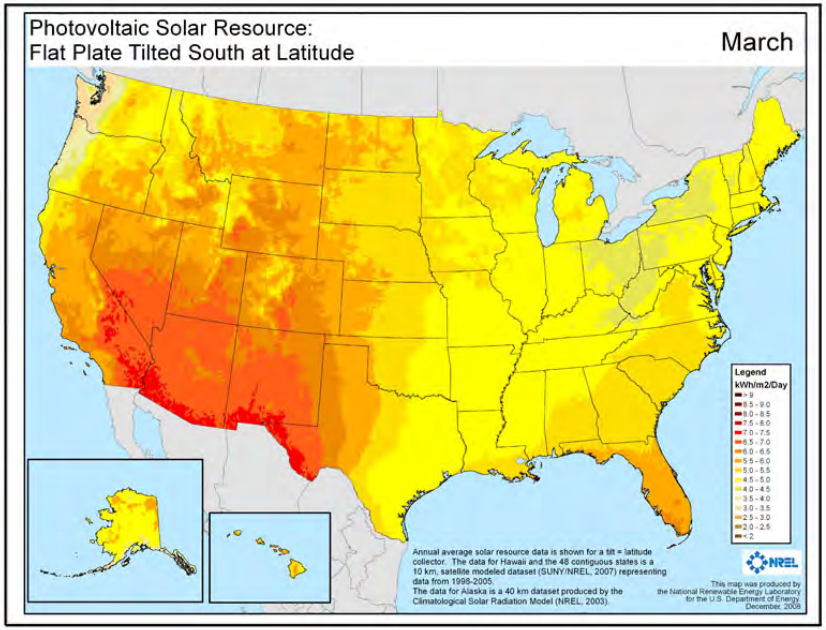
R.M. YOUNG COMPANY

2801 AERO PARK DRIVE, TRAVERSE CITY, MICHIGAN 49686, USA

TEL: (231) 946-3980 FAX: (231) 946-4772

Solar

- Long Wave
  - Wave Length and Spectrum
- Short Wave
  - Wave Length and Spectrum
- Resolution
  - Angle of Incidence
  - Area
    - Snow Flake/Granual
    - Area albedo



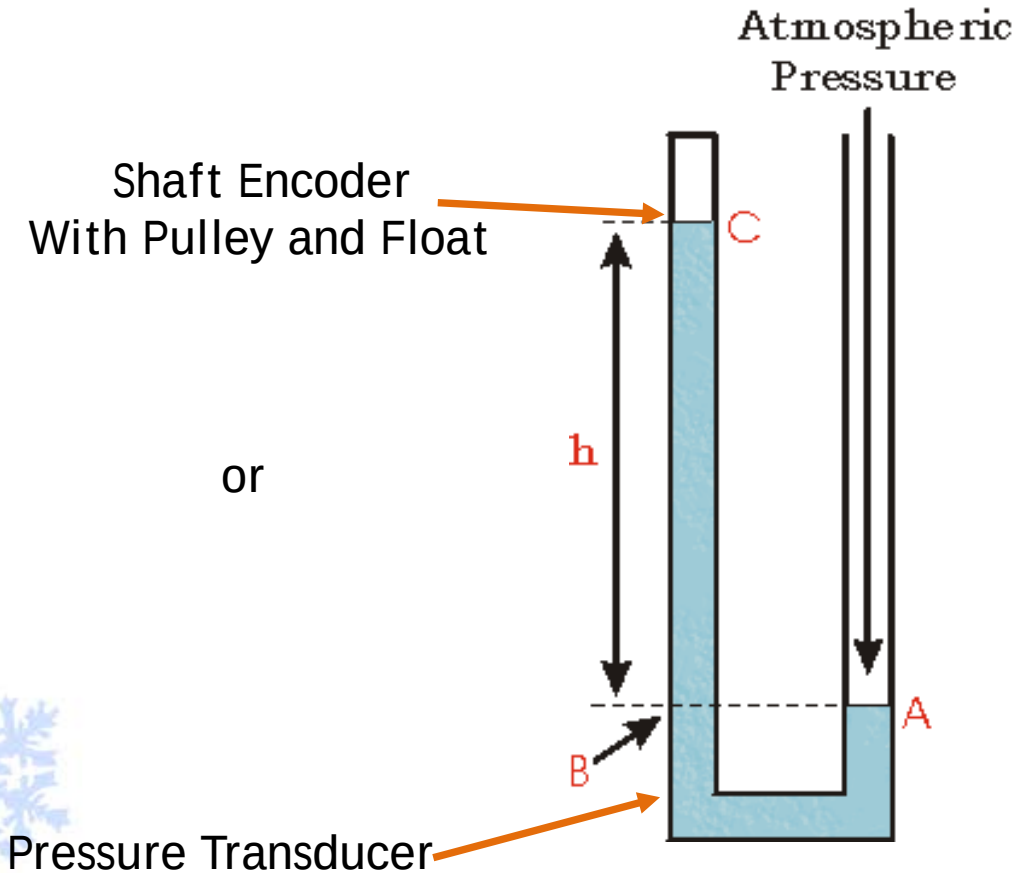
Solar Continued

- Output Parameters: Solar Radiation (W/m^2) , Solar Irradiation (W/m^2)
- Sample Frequency: 20min

Snow Water Equivalent

- Snow Pillows
  - Manometers (Open System)
    - Pressure Transducers
    - Encoders
  - Pressure Transducer (Closed System)
- Snow Scale
- Gamma Sensor (Cosmic Rays)

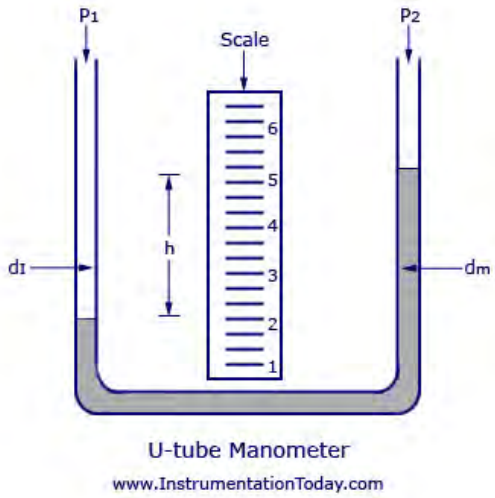
Manometer


Atmospheric
Pressure
Shaft Encoder
With Pulley and Float
or
C
h
A
B
Pressure Transducer

Snow Manometers Encoders

Pros

- No Electrical Calibration
- SDI 12
- Extremely Accurate if used properly
- Low Voltage Consumption



Cons

- Fluid Specific (Volumetric)
  - Adjustment in Data Acq
  - Difficult (resources/communication)
- Different Pulley Sizes
- Bearings wear and need to be replaced
- Lots of Moving Parts
- Weights
- Pulley Tapes sizes
- Fluids need to be replaced
- Snow Pillows can be punctured Easily
- Ground Based
  - Ice Bridging
  - Edge Effect

Snow Manometers
Pressure Transducers

Pros

- Fluid Agnostic (Pressure)
- Low Voltage Consumption
- Light Weight
- Small for Packs
- Water Proof

Cons

- Electronic Calibration
- Fail if wet (Non-Submersible)
- Wrong Output based on type
  - PSIS, PSIA, PSID
- Snow Pillows can be punctured easily
- Ground Based
  - Ice Bridging
  - Edge Effect

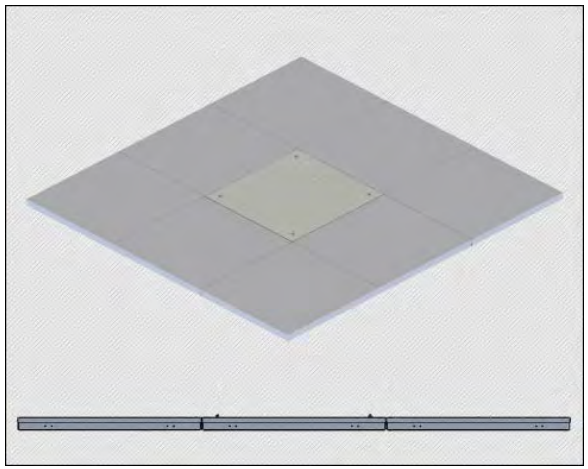
Snow Water Equivalent
Snow Scales (Load Cell)

Pros

- Fluid-less
- Easier To Pack Back
- Withstand over 2500lbs

Cons

- Electronic Calibration
- Ground Based
  - Ice Bridging
  - Edge Effect



Snow Water Content
Submersible PT/Encoder/Scale

- Output Parameters: SWE (inH2O)
- Sample Frequency: 20 min

Snow Depth Sensor

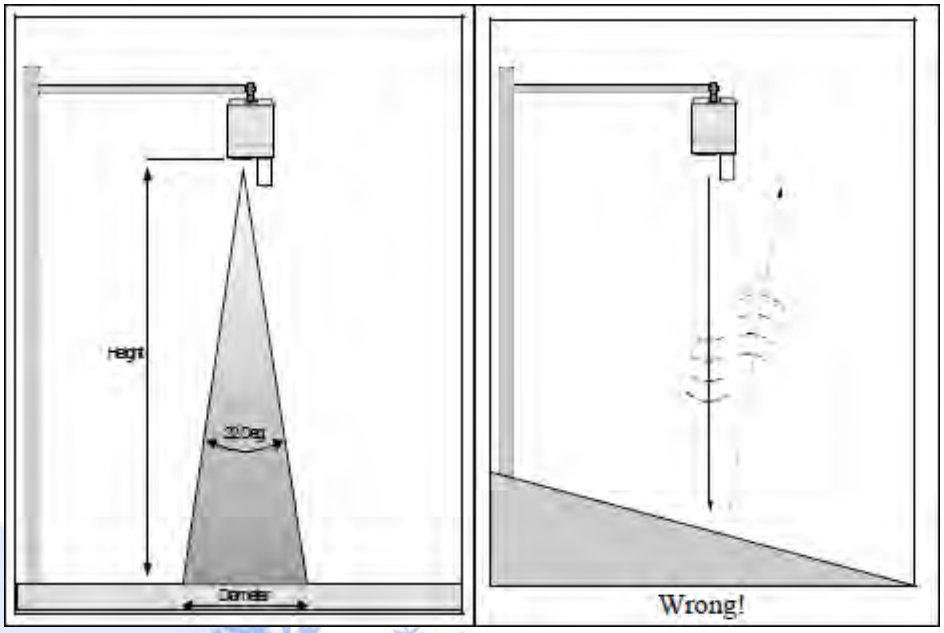
Judd Sonic Depth Sensor

SHM-XX Laser Depth

Snow Depth
Sonic

Pros

- Small and Light



Cons

- Wind can effect signal
- Speed of sound changes based on temperature
- Onboard Temperature Sensor Dependent
- Needs to be installed perpendicular to surface.

Snow Depth Laser

Pros

- Light Based
- Not affected by wind
- Not affected by Temperature
- Tilt-able
- High Accuracy

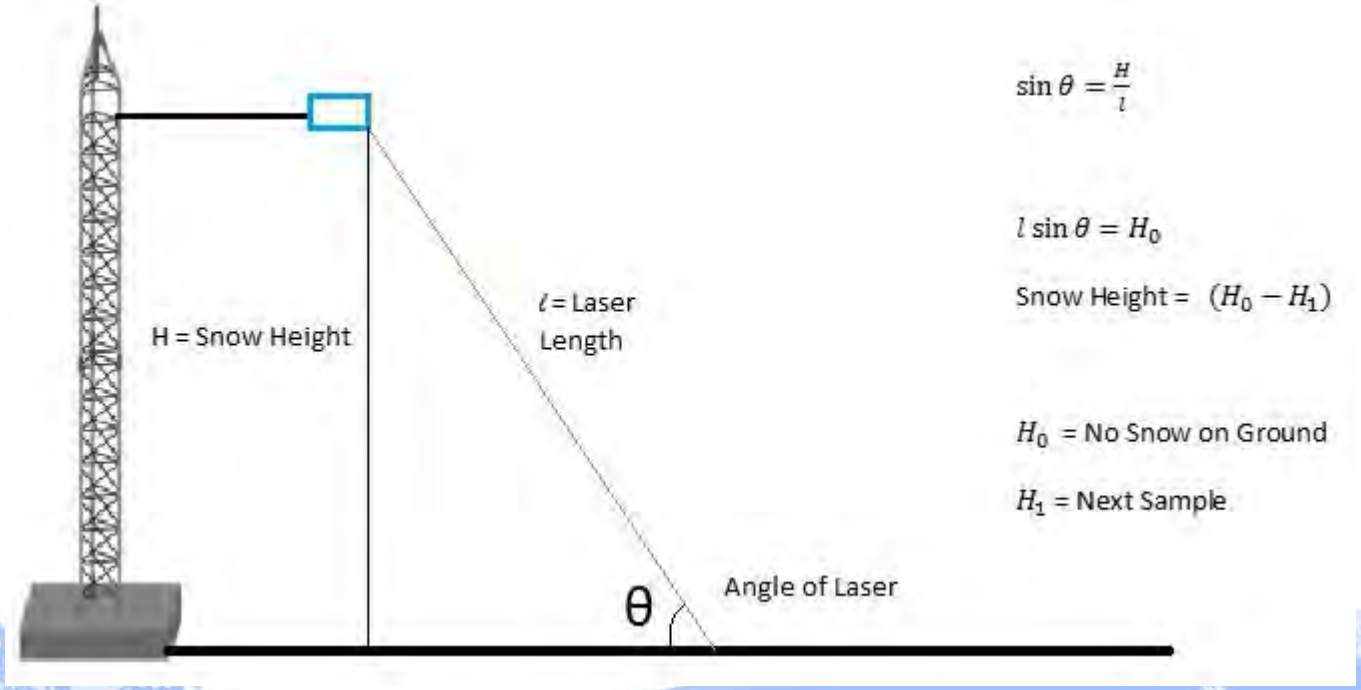
Cons

- Power Consumption
- Heavy
- Wrong Readings if adjusted improperly

Snow Depth

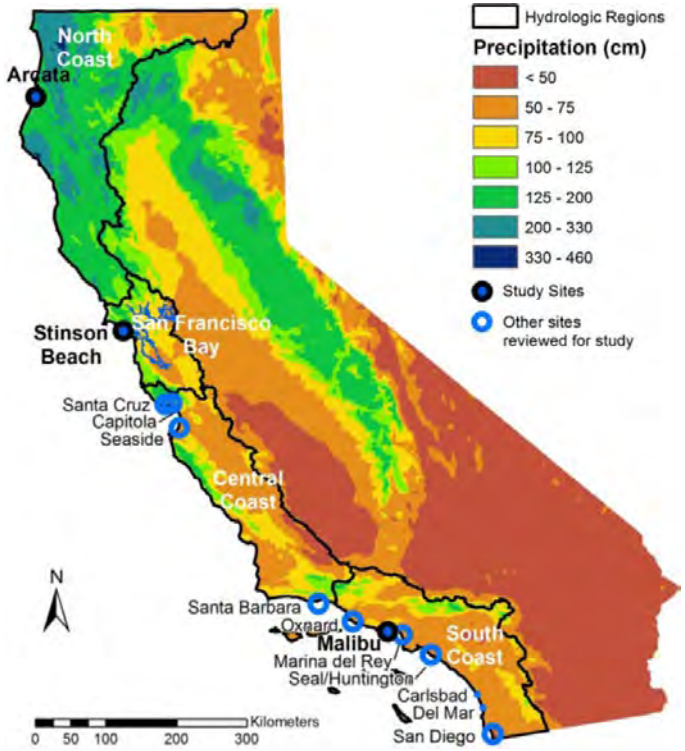
Snow Depth – Judd Transitioning to SHM-30

- Output Parameters: Snow Depth (in)
- Sample Frequency: 20min



Precipitation (Still Researching)

- Tippers
  - Overflow
  - Heated
- Manometers
  - Encoders
  - Pressure Transducers
- Radar



Precipitation Tippers

Pro

- Accurate if Leveled
- Heater for Snow
- Fluid option for snow
- Easy Installation
- Hall Effect Sensor

Cons

- Unlevel = inaccurate
- Heater uses lots of power
- Fluid Needs to be replenished
- Top of Tipper Catch susceptible to clogging

Precipitation Manometers Encoders

Pros

- No Electrical Calibration
- SDI 12
- Extremely Accurate if used properly
- Low Voltage Consumption

Cons

- Fluid Specific (Volumetric)
  - Adjustment in Data Acq.
  - Difficult (resources/communication)
- Different Pulley Sizes
- Bearings degrade and need to be replaced
- Lots of Moving Parts
- Weights
- Pulley Tapes sizes
- Fluids need to be replaced
- Large Foot Print

Precipitation Manometers Pressure Transducers

Pros

- Fluid Agnostic (Pressure)
- Low Voltage Consumption
- Light Weight
- Small for Packs
- Water Proof

Cons

- Electronic Calibration
- Fail if wet (Non-Submersible only)
- Wrong Output based on type
  - PSIS, PSIA, PSID
- Large Foot Print

Temperature

Common Types

- Negative Temperature Coefficient (NTC) Thermistor
- Resistance Temperature Detector (RTD)
- Thermocouple
- Semiconductor based

Negative Temperature Coefficient (NTC)

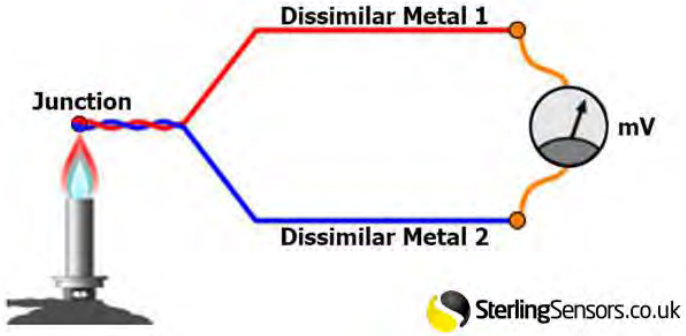
- Thermistor Based
- Thermally sensitive resistor
- -50 to 250 degrees Celsius
- Fast Changing environment
- Non Linear

Resistance Temperature Detector (RTD)

- Linear Output
- -200 to 600 Degree Celsius
- Film and wire wrapped
- High resolution

Thermocouple

- Made of two types of metal wire
- Low Accuracy
- -200 to 1750 degree Celsius
- Based on materials and thermocouple type
- Non – Linear (Close to linear)



Semiconductor-Based Sensors

- Integrated Circuit Based
- Diode Based
- Linear Response
- Low Accuracy
- Low Temp Range (-70 to 150 degree Celsius)

Temperature

Temp and RH – Rotronic HC2-S3 and EE181

- Output Parameters: Temp (Deg F) , RH (%)
- Sample Frequency: 20min

Relative Humidity

- Normally Included on Temp Sensors
- Make sure it is potted to protect from condensation and water

Wind

Sonic

Anemometer

Wind (Sonic)

Pros

- Accurate
- SDI-12
- High Max Wind Speed
- No moving parts

Cons

- Icing Creates unreliable Measurements
- Not Hydrophobic
- Calibration is difficult
- Orientation and Data Acquisition
- Bird Nests

Wind – HD Alpine (Anemometer)

Pros

- Accurate
- Self Powering Wind Speed
- Hydrophobic Coating
- Easy Calibration (field)
- Swept Back Blade Pitch

Cons

- Potential Hard Snow Build up on prop
- Plastic Coating Could create vulnerability in transportation
- Ceramic Bearing replacement
- Target Practice
- Orientation and Data Acquisition

Wind – HD Alpine or Sonic

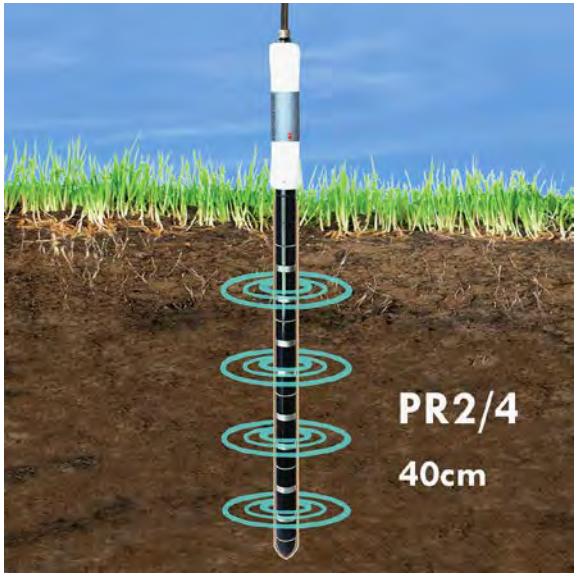
- Output Parameters: Wind Speed (mph) , Wind Direction
    - (Degrees reference to True “North”)
- Sample Frequency: 20min
- Total Samples/hr = 3 per Speed, 3 per Direction = 6

Soil Moisture Probes

Soil Probes Types

- Coaxial Impedance Dielectric Reflectometry
- Time Domain Reflectometry (TDR)
- Frequency Domain Reflectometry (FDR)
- Time Domain Transmissometry
- Gypsum Blocks
- Neutron Probes
- Gravimetric Probes

End Goal: Volumetric Water Content



Soil Moisture Probes – Hydra Probe II

- Output Parameters: Soil Temp (Deg F), Soil Moisture (%)
- Depths (USGS/NRCS Soil Scientists Collaboration):
  - 25cm, 50cm, 100cm or 50cm, split the difference
- Sample Frequency: 20min
- Soil Moisture = 3/hr from 3 probes = 9/hr
- Soil Temperature= 3/hr from 3 probes = 9/hr
- Total Samples/Hr = 18

California Climate Snow Station

HyDAS Output Parameters

- Parameters:

1) Barometric Pressure = 3/hr
2) Precipitation = 3/hr
3) Wind Speed = 3/hr
4) Wind Direction = 3/hr
5) Temperature = 3/hr
6) Relative Humidity = 3/hr
7) Solar radiation = 3/hr
8) Solar Irradiation = 3/hr
9) Soil Moisture (3 Depths) = 9/hr
10) Soil Temp (3 Depths) = 9/hr
11) Snow Water Content = 3/hr
12) Snow Depth = 3/hr

Total = 16 parameters every 20min, or 48 parameters every hour

Data Transmission

GOES (One Way)

- 300 Baud 10sec
- 1200Baud
  - 1200 Baud = 15min ASCII data
- Two Way Communication

Antenna Types and Communication

Yagi Antenna

FTS EON2 GOES Antenna

Antenna Comparison

Yagi Antenna

- Higher Gain
- Directional
- Ice Builds Up
- Transport then assemble
- External GPS required

FTS EON2 GOES Antenna

- Lower Gain
- Omnidirectional
- Water and Snow shedding
- Little to no Assembly required
- Internal GPS option

Design Integration

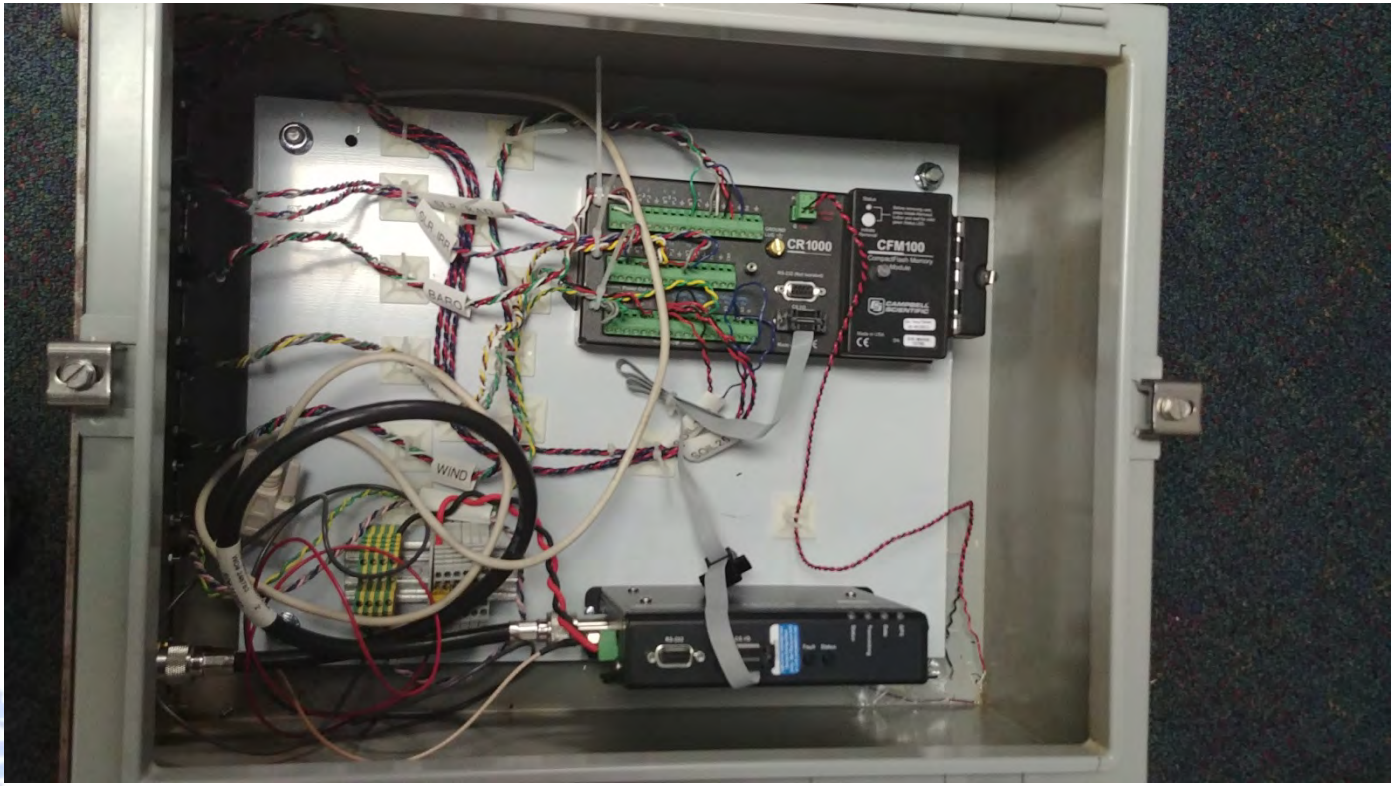
Best way to integrate instruments

- Open Architecture
- Interoperability for the future
- Easy to work on in the field

Enclosure Design

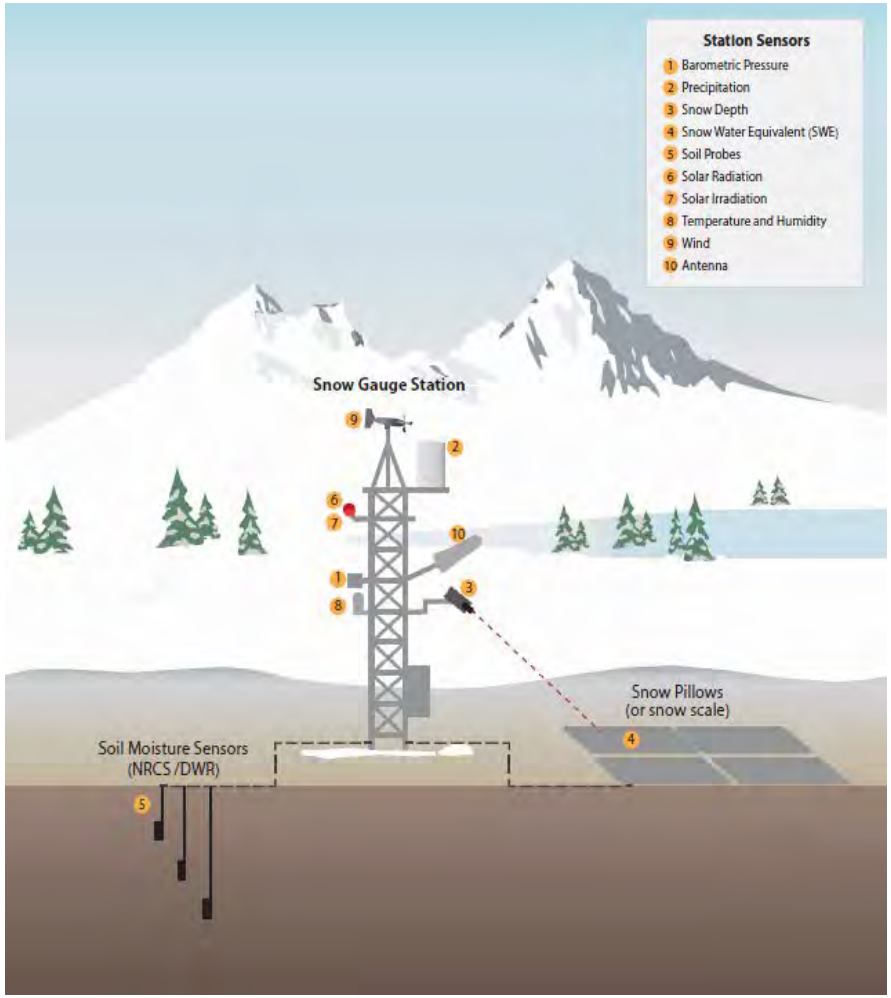
- Interoperability of the enclosure specifically with connector design on the bottom of electrical enclosure.
- Quick connect and disconnect connectors to allow for easy and safe exchange of instruments that require calibration or replacement

RPU Enclosure continued



Completed New Design:

HyDAS Station



	Old Standard	New Standard
Precipitation	✓	✓
Snow Depth	✓	✓
Snow Water Content	✓	✓
Temperature	✓	✓
Barometric Pressure		✓
Wind Velocity		✓
Relative Humidity		✓
Solar Radiation		✓
Solar Irradiation		✓
Soil Moisture		✓

Highland Meadows

Stanislaus National Forest

Highland Meadows (HHM)

The First of Many

- First Upgraded DWR snow surveys station
    - California Climate Snow Station (CCSS)
- 16 Parameters every 20min = 64/hour
- Intent
    - Direct variables for Basic Water Information (BWI)
    - More Accurate BWI for Models
    - MORE DATA!!!!

Highland Meadows (HHM) Cont.

Highland Meadows (HHM) Cont

Highland Meadows Vulnerabilities

The Grass Eaters – aka the Cows

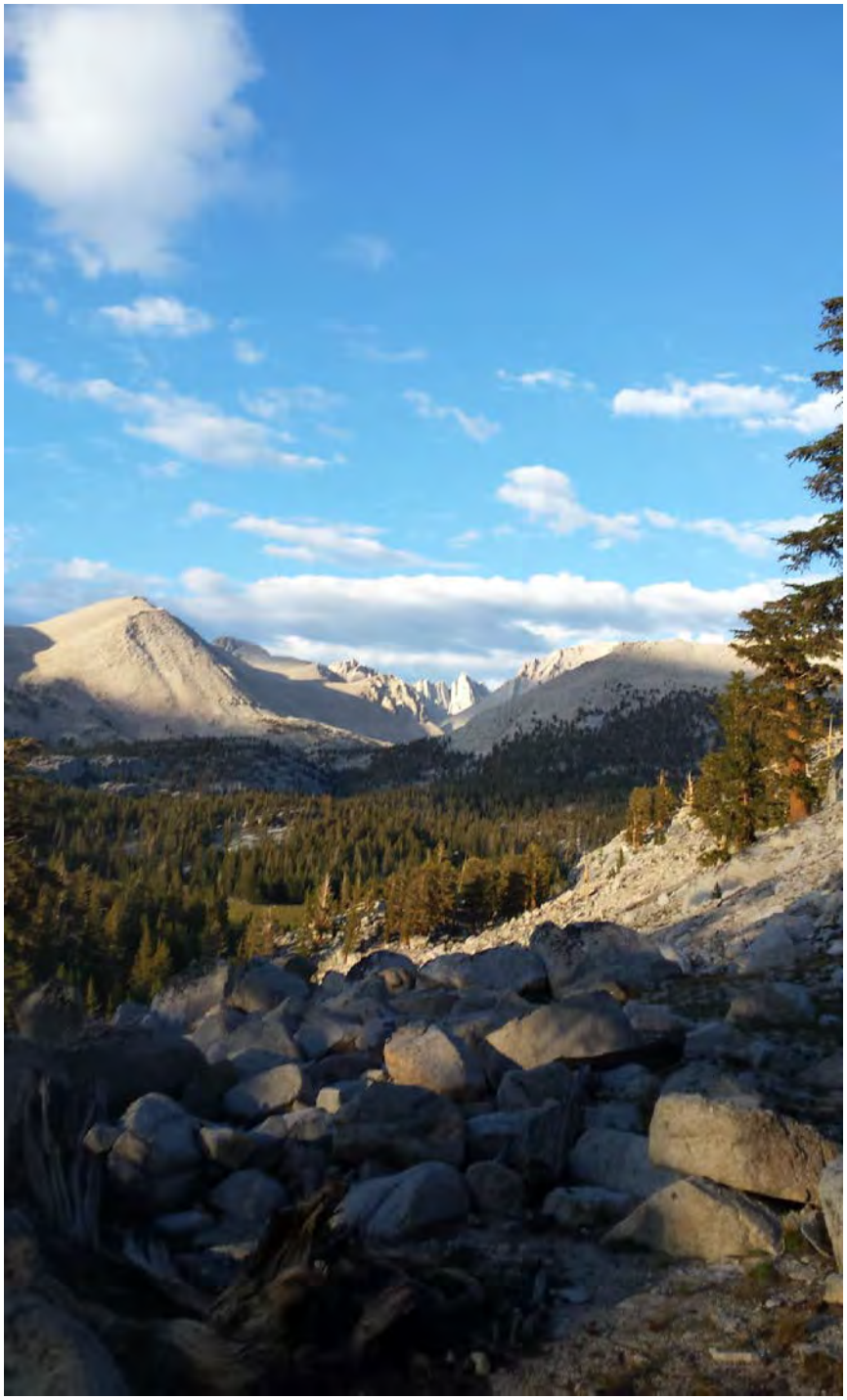
What is going on behind the scene?

Transportation

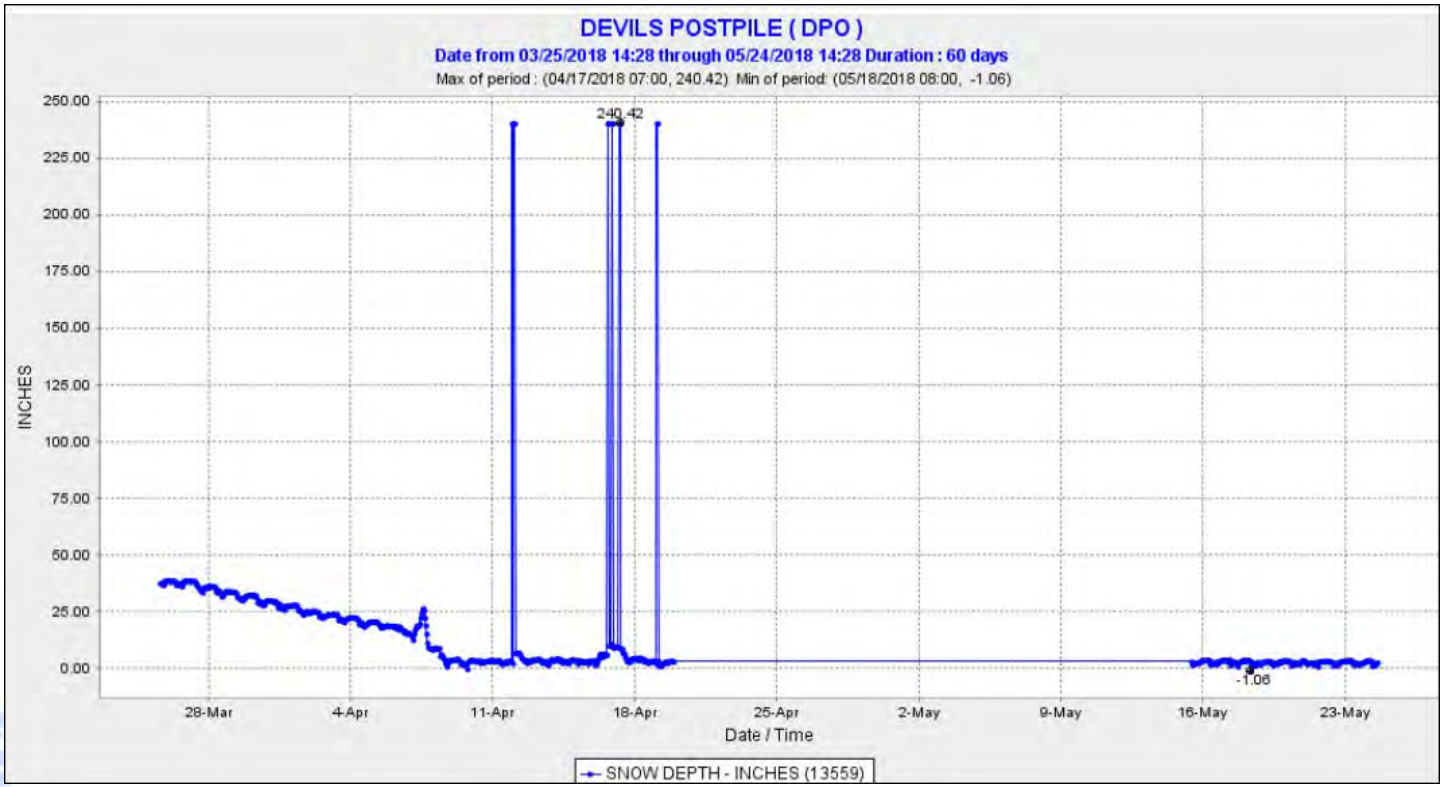
Farewell Gap

Argo with Snow Treads

Bishop Pass (BSH)



Data Management



Data Management

Data QA/QC

- RAW Data in CDEC
- Maintainers do not QA/QC the Forecasters control QA/QC
- Issues
  - Careful where you are changing data – erasing or modifying
  - Are you looking at the data and figuring out why and taking it at face value? Or manipulating/changing the data to what YOU think it should be?

Data Management

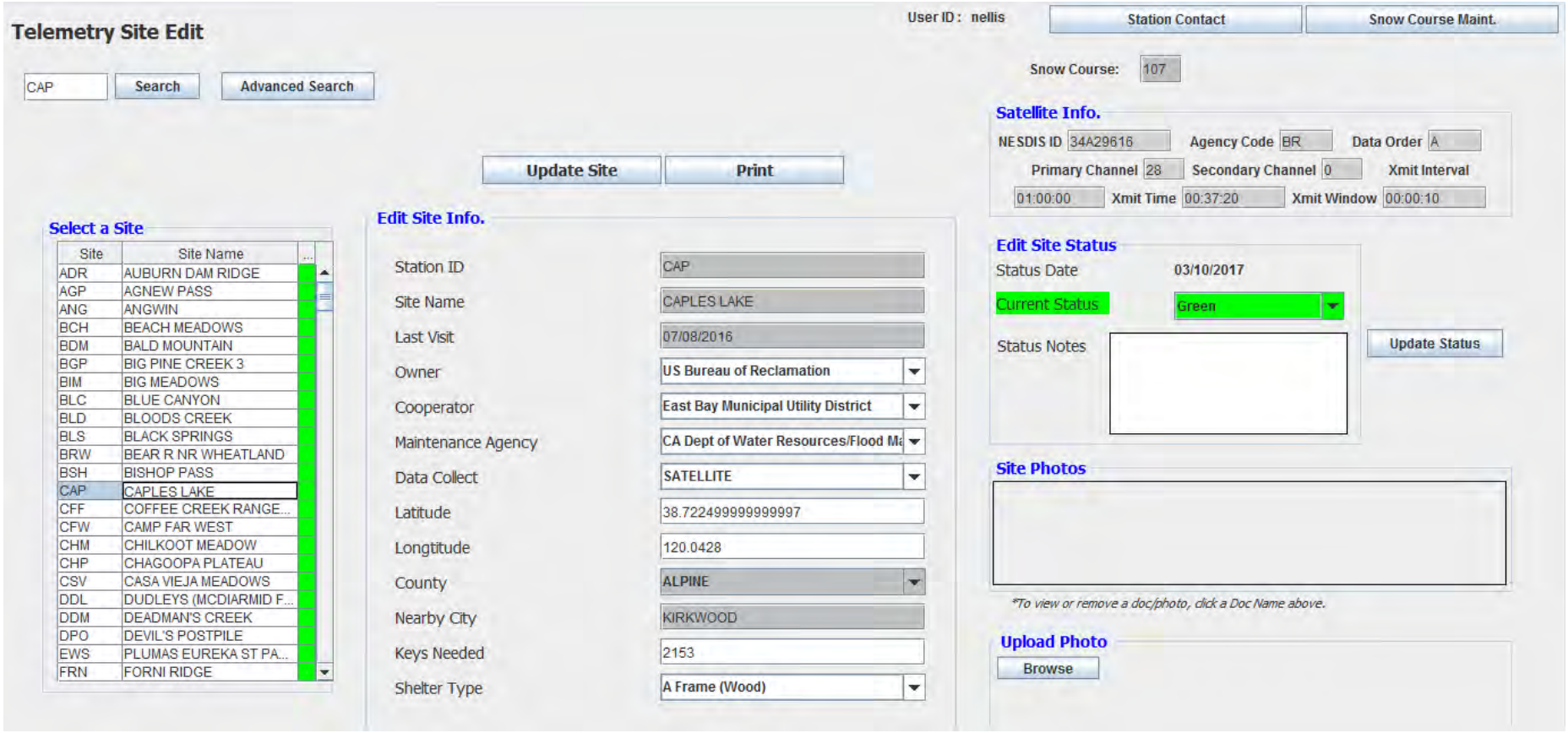
Where is it going?

- End Users wants:
- Example:
  - DCP multipoint sampling/min/max/avg
    - Min Avg, Max Avg , Avg
    - Min Min, Max Min, Min
    - Min Max, Max Max, Max
  - How many points? What is the sampling? Data Set? Period?
  - Getting Complicated

Software

- Introducing an indicator script that will monitor and analyze data to inform persons via email of bad or missing data.
- Improve transparency and communication on status of stations for maintainers and hydrographers
- Easy to use and adjust data logger software for field operations. Implementing handheld device (CR1000KD) for fields calibration and sensor replacement
  - Fully Configurable Constant Table for Station Instruments

Telemetry Application



Telemetry Sites Status

Legend:

- Station is 100% working.
- One or more items is uncalibrated or broken or needing repair – however the primary sensors are still in tact.
- Station failure, or primary sensor failure.

Sort Site ID (a-z) ▾ Filter RIVER BASIN ▾

Site ID	Site Name	Status	Notes	Last Visit
ADR	AUBURN DAM RIDGE			05/29/2014
AGP	AGNEW PASS		visited 8/17/17 - depth is good just tall grass, pillows are intact no leak.	09/13/2016
ALY	ALLEGHENY		Precip not accurate	11/18/2014
ANG	ANGWIN			03/19/2014
ARC	AARCATA			12/03/2012
ATL	ATLAS PEAK			03/19/2014
BCB	BLACKCAP BASIN		Battery Dropped below 10V, station down and tower collapsed.	10/15/2005
BCC	BLACK CREEK NR. COPPEROPOLIS			06/09/2010
BCH	BEACH MEADOWS		Precip was Reset 6/7/2017	06/07/2017
BDM	BALD MOUNTAIN			12/23/2016
BFL	BIG FLAT			08/05/2014
BGP	BIG PINE CREEK 3		Replaced SWE Pressure Transducer 8/15/17	07/27/2016
BGV	BRIDGEVILLE PRECIP			12/11/2013
BIM	BIG MEADOWS			10/26/2015
BLA	BLACKS MOUNTAIN		Snow Depth Needs to be replaced	08/03/2016
BLC	BLUE CANYON			06/27/2017
BLD	BLOODS CREEK			08/09/2017
BLM	BLACK MOUNTAIN			01/22/2015
BLS	BLACK SPRINGS			08/15/2017
BNK	BONANZA KING			08/11/2016
BOL	BOWMAN LAKE		Precip not accurate	02/19/2015
BRA	BRADLEY			01/21/2015
BRI	BRIDGEVILLE			10/30/2014
BRS	BRUSH CREEK			06/21/2006
BRW	BEAR R NR WHEATLAND			05/31/2017
BSH	BISHOP PASS		Needs new Batt, snow depth, and PT	11/12/2015
BUD	BULLARDS BAR			10/16/2015
BUL	BULLARDS DAM			01/26/2006
CAP	CAPLES LAKE			07/08/2016

Telemetry Sites Status

Legend:

- Station is 100% working.
- One or more items is uncalibrated or broken or needing repair – however the primary sensors are still in tact.
- Station failure, or primary sensor failure.

Sort: Site ID (a-z) ▼

Filter: AMERICAN R ▼

Site ID	Site Name	Status	Notes	Last Visit
ADR	AUBURN DAM RIDGE			05/29/2014
BLC	BLUE CANYON			06/27/2017
CAP	CAPLES LAKE			07/08/2016
CBR	AMERICAN RIVER AT CHILI BAR			08/02/2011
FRN	FORNI RIDGE			08/19/2016
GKS	GREEK STORE			10/26/2016
GTW	GEORGETOWN			06/25/2014
HYS	HUYSINK			08/03/2017
LOS	LAKE LOIS		10/31: Upgrade! DEPTH NOT WORKING	12/04/2006
OXB	MIDDLE FK AMERICAN R NR OXBOW PH			04/23/2014
PFH	PACIFIC HOUSE			07/02/2014
PWS	PLACERVILLE WEATHER STATION			05/16/2016
SGP	SUGAR PINE			06/25/2015
SIL	SILVER LAKE		Depth Sensor Replacement Required	07/06/2016

Future Development

Joint Field Instrumentation Plan

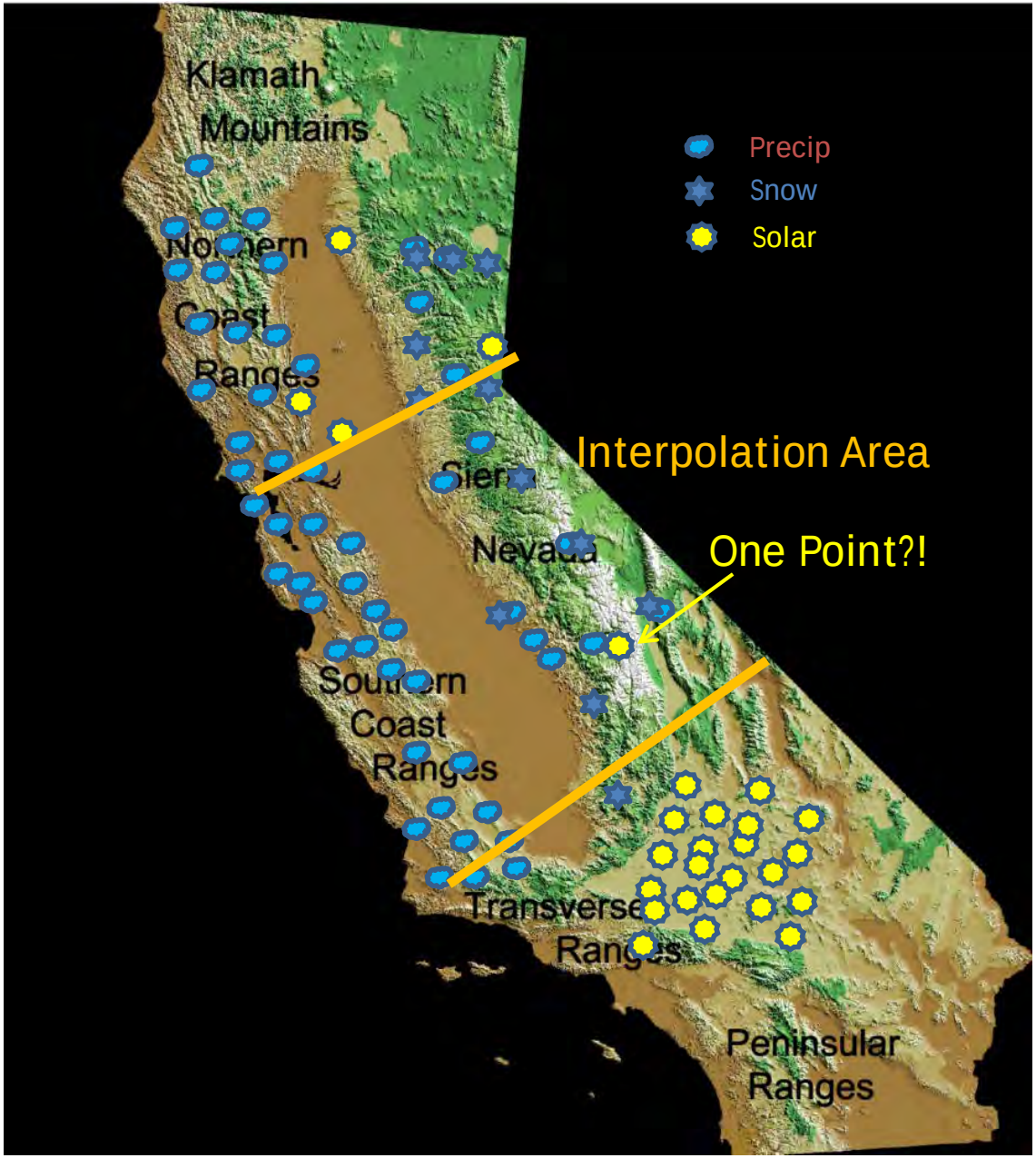
- Create Standard California Suite of Sensors
- Every Station in California has at a minimum the “California Designed Suite” of sensors.
- Utilize other Agency stations, and resources to help outfit each others station with useful instruments.

Folsom Lake

Better Data means a better understanding to better our resource management.

Joint Field Instrumentation Plan JFIP

- More Data
  - Fills in the “gaps”
- All in one California station Network
  - Nodal Mesh Network of California's Weather Stations


Klamath Mountains
Precip
Snow
Solar
Interpolation Area
One Point?!
Coast Ranges
Peninsular Ranges

Future Development

Joint Field Instrumentation Plan JFIP

- Standardizing All Agency Sites in California
- Uniform Data Acquisition
- Cooperative Agencies Who Will Benefit
  - NRCS
  - USGS
  - National Wildfire Coordinating Group
  - Water Agencies
  - Forecasters
  - Avalanche Centers
  - NPS
  - USFS
  - Public/Recreationalist
  - Academia


Questions?

Thank you

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