30 June 2006

Summary of 22 June HMT meeting in Sacramento

Attendees:

Chris Anderson	ESRL/GSD	Brooks Martner	ESRL/PSD
Steve Goldstein	STO WFO	John McGinley	ESRL/GSD
Art Henkel	CNRFC	Betsy Morse	STO WFO
Dave Jorgensen	NSSL	Josh Nowlis	NMFS/SFSC
Wes Junker (phone)	NCEP/HPC	Marty Ralph	ST&I, ESRL/PSD
John Juskie	STO WFO	Dave Reynolds	MTR WFO
Dave Kingsmill	ESRL/PSD	Paul Schultz	ESRL/GSD
Dave Kitzmiller (phone)	OHD/HL	Mike Smith	OHD/HL
Jessica Lundquist	ESRL/PSD	Kevin Werner	WR HQ

The following pages contain the "white-papers" that were discussed at the meeting. They are:

1. **QPE Processing Status Overview**
2. **Debris Flow Report**
3. **QPF Verification Issues**
4. **Streamflow Verification Issues**
5. **Experimental Design / Research to Operations Issues**
6. **HMT Mesonet Issues**
7. **HMT Outreach Ideas**

Comments and questions that arose during our discussions are listed at the end of each white paper. A summary of overall HMT-West priorities that emerged from all of the discussions is listed below:

- The top QPE priority is to provide radar (and gage) QPE in the upper NFARB and lee side.
- If scanning radar operations are not possible during HMT-West 2007, then the next highest observational priority is to better map snow level in the upper part of the NFARB and in the lee using profilers, disdrometers and micro-temperature sensors.
- The top QPF priority is to provide high resolution model output (both deterministic and probabilistic) to forecasters at CNRFC and WFOs via AWIPS and/or ALPS workstations.
- Secondary QPF priorities are validation via NPVU and HMT data assimilation denial experiments.
- A priority that crosses over between QPE and QPF is to integrate HMT datasets, particularly QPE from scanning radars, into Q2 for the purpose of advancing QPF validation.
- The top programmatic priority is to fund and appoint a full-time, Federal-employee Manager to direct the HMT program.

1. QPE Processing Status Overview

Background. NOAA's Hydrometeorological Testbed (HMT) field deployment in Northern California has resulted in an unprecedented amount of radar data collection in heavy precipitation events over the American River Basin (ARB). Well over 70 inches of precipitation fell from 1 December to 8 March in 13 Intensive Operational Periods (IOP) in the upper reaches of the ARB. Data has been archived for each IOP for the portable Doppler radars (1) NSSL SMART-R (C-band) at Foresthill and the (2) ETL XPOL (X-band) at Auburn as well as the WSR-88D radars located at Sacramento (KDAX) and Beale AFB (KBBX). By virtue of their proximity to the ARB, the portable radar observations had superior spatial resolution to those of the WSR-88D. The X-Pol radar also had polarimetric measurement capabilities that are not yet available on the WSR-88D units.

Data Processing Status(NSSL focus). To compute Quantitative Precipitation Estimates (QPE) the radar data must first be interpolated to Cartesian grids and then rainfall calculated via an empirical Z-R relationship. Software has been completed to perform interpolation to a 1 km by 1 km by 250 m x,y,z grid. Radar data is then masked with a digital topographic data set interpolated to the same grid to eliminate ground return. Rainfall is calculated by using the lowest grid points to the ground (generally within 200-500 m of the surface) using the relationship $Z=300R^{1.4}$ for a test case from IOP 12. As an illustration, a comparison of the resultant rainfall rates (mm/hr) for a 5 volume scan at 0625 UTC from both the SMART-R and KDAX radars is shown in Fig. 1. This time period encompassed the passage of a narrow cold frontal rainband over the ARB, and was one of the strongest convective echo cases during HMT. Maximum rainfall rates from the SMART-R exceeded 400 mm/hr in the convective line, while the KDAX indicated only maxima of ~80-100 mm/hr. Detailed comparisons with the HMT raingages will be performed to quantitatively evaluate the value of the two gap filing radars (SMART-R and XPOL) on the QPE for each IOP. Additionally, once all the radar data is gridded hourly basin total precipitation from those bins located over the ARB will be accumulated for input into hydrologic models to compare to streamflow measured by hydrographs on the river as a tool to evaluate QPE improvements over the operationally available data sets.

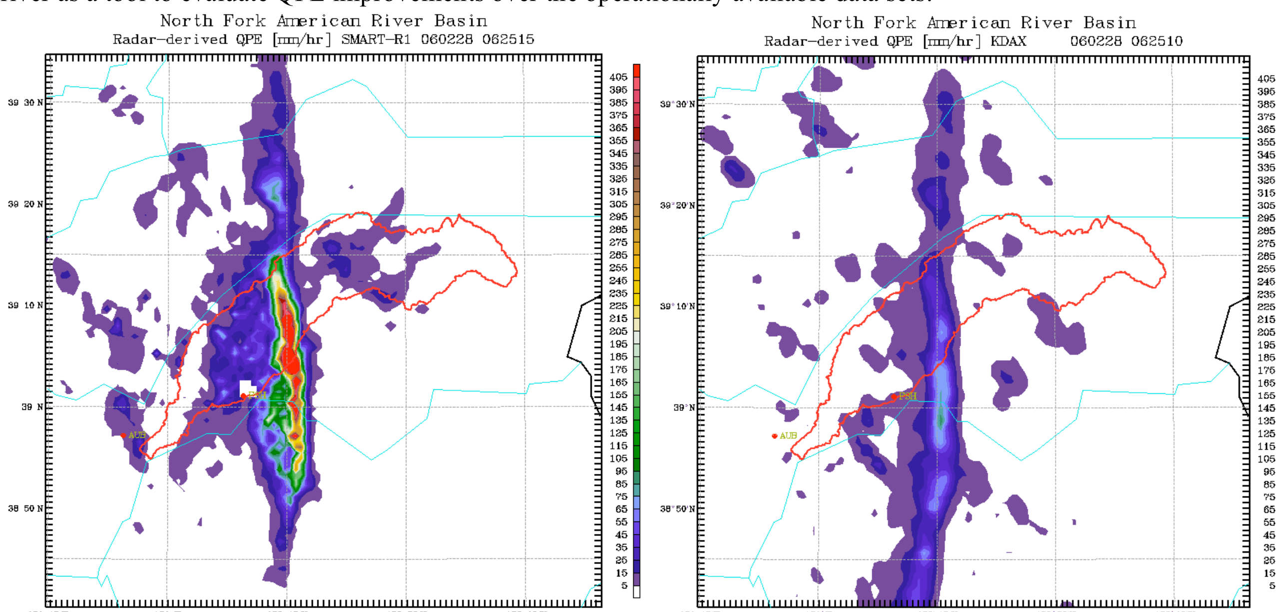

Fig. 1. Radar-derived QPE [mm hr^{-1}, contour scale on right) from the SMART-R radar (left panel) and the WSR-88D Sacramento radar KDAX (right panel) for 0625 UTC on Feb. 28 2006 (IOP 12). Blue thin lines are county boundaries and the red outline is the ARB. The western part of Lake Tahoe is outlined in black. Locations of the SMART-R at Foresthill, CA is indicated by the red dot.

Other planned activities:

1) Evaluation of appropriate Z-R relationships.
2) Elimination of "bright band" biases
3) Advantages of using dual-polarization parameters to improve QPE.

Data Processing Status (ESRL/PSD focus). Drop size distributions (DSDs) collected during the HMT-06 field campaign have been analyzed. These DSDs were obtained using an impact Joss-Waldvogel disdrometer (JWD) which was deployed at the primary ground validation site located at the Colfax water center (CFC). Using these DSDs , an X-band Z-R relation representative for the HMT-06 was developed (Z_{eh}=100 $R^{1.76}$). Note that this relation is generally suitable also for longer wavelengths (S- and C- bands) because the relative number of larger drops that cause non-Rayleigh effects was small. DSD data were also used to develop a customized HMT-06 relation between rainfall rate and the specific differential phase (K_{DP}) for the mean drop shape model (i.e, R=17 $K_{DP}^{0.7}$). The NOAA ESRL attenuation (for reflectivity, Z_{eh}) and differential attenuation (for differential reflectivity, Z_{DR}) correction algorithms have been tuned specifically for the HMT-06 data set. IDL program codes have been developed to perform interpolation of the NOAA/ESRL X-POL data to the Cartesian 500 m by 500 m grid. The developed codes provide retrievals of instantaneous rainfall rates using (i) the mean Z-R relation (Z_{eh}=100 $R^{1.76}$), (ii) the mean K_{DP}-R relation, and (iii) the combined polarimetric estimator (CPE) that uses measurements of Z_{eh}, K_{DP}, and Z_{DR} and inherently accounts for a variability of the drop shape – drop size relation. These developed codes also calculate time series of rainfall accumulation and present these accumulations on the same 500 m by 500 m grid. An illustration of the NOAA/ESRL X-POL derived rainfall accumulations is shown in Fig. 2. The accumulations in this figure correspond to the results obtained with the combined polarimetric estimator. Results are shown for the total duration of IOP-04 which produced the largest total amount precipitation during HMT-06. The radar was scanning in the sector between about 0 (due north) and 90 (due east) degrees in the American river basin. Due to the mountainous terrain, the lowest elevation angle possible with the X-POL radar was 3 degree. It resulted in the strong bright band features beyond about 25 km in range. No attempt has been made so far to make QPE in the bright band and in the snow region beyond. The location of the CFC ground validation site is also shown in Fig. 2. Note that an arc-shaped area of enhanced accumulation at about 3 km range is caused by the ground clutter. Figure 3 shows the time series of rainfall accumulations over the CFC site obtained by the 3 different X-POL rainfall estimators and the ground "truth" results calculated using the CFC JWD DSDs. It can be seen that the combined polarimetric estimator provided the best agreement with the JWD data.

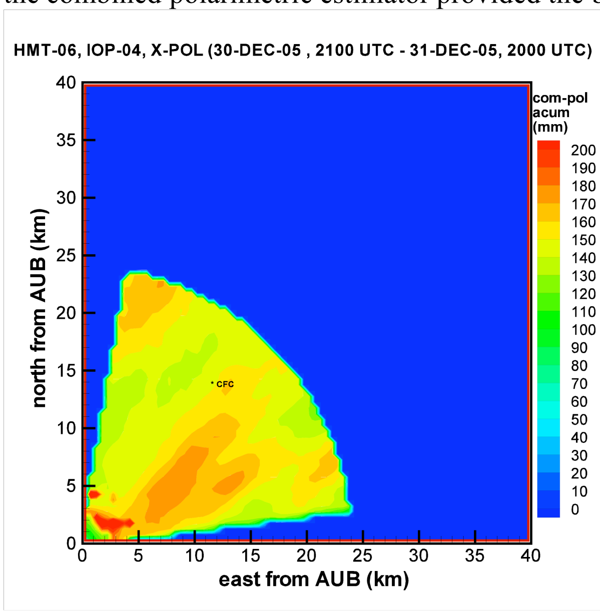

Fig.2. A rainfall accumulation map in the area of the NOAA/ESRL X-POL HMT-06 sector scan. The radar Location at AUB had coordinates 38.95408 deg N, and 121.07608 deg S. The data presented are for the IOP-4.

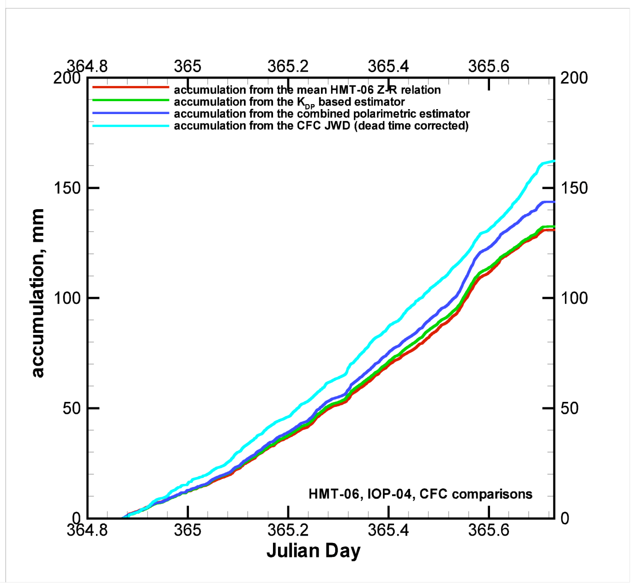

Fig.3. Time series of the X-POL rainfall accumulations from different estimators using X-POL polarimetric measurements and the ground JWD data (IOP-04).

Other planned activities:

1). Continuation of the analysis of other IOPs.

2). Developing the procedures of QPE in presence of bright band and snow.

Comments/Questions associated with **QPE Processing Status Overview**

- There were questions about what fraction of the North Fork American River Basin (NFARB) the two gap-filling radars were able to sample. XPOL sampling was limited to the lower portion of the basin (within 30-40 km range upslope from Auburn). SMART-R was able to sample the entire basin, although there may be data limitations in the upper part of the basin toward the ENE to E due to tree blockage near the Foresthill site.
- There was a question about integration of gap-filling radar data into the national Q2 QPE mosaic. This will happen eventually, but is being delayed while the Q2 algorithms become more stable.
- There was a question about calibration of SMART-R. It is periodically calibrated internally. It was suggested that external calibration with disdrometer data at Colfax could also be explored.
- There was a suggestion that DMIP-2 would value having the full ensemble of QPE products that can be generated from XPOL and SMART-R, not just the single QPE product that is deemed “best” (e.g., Z-R, Kdp-R, combined polarimetric estimator, various vertical profile of reflectivity correction techniques, etc.)
- There was a suggestion that Q2’s blended estimates of rainfall rate from gauges and radar should be compared with the NPVU estimates of rainfall rate from gauge data modified for the assumed effects of orography.

2. Debris Flow Report

(Prepared by B. Martner, D. Jorgensen, and K. Werner)

NOAA’s Hydrometeorological Testbed (HMT) in Northern California and the new USGS-NOAA Debris Flow project in Southern California share interests in improving the monitoring and forecasting heavy winter precipitation over complex terrain and addressing its hydraulic impacts. They also share some of the same scientists and kinds of observing equipment. At present, however, the physical separation of the two projects and very limited funding have prevented any effective merger and leveraging of research activities of the two programs.

Debris flow is a type of landslide initiated when heavy rainfall mobilizes soil on steep slopes, sending a slurry of rocks, soil, mud, and water downhill with tremendous force. Mountainsides denuded of vegetation by recent fires are particularly vulnerable to these flows, which often kill nearby residents and destroy homes and structures. Geologists have derived empirical relations between rain accumulation and the likelihood that debris flows will occur for specific sites.

In 2005 the USGS and NOAA signed a Memorandum of Understanding for cooperative action regarding debris-flow forecasting, and outlined a program for operations and research (http://pubs.usgs.gov/circ/2005/1283/). The joint-agency plan calls for a regional debris flow forecast/warning demonstration for most of Southern California, including the establishment of an Intensive Research Area (IRA) in a recently burned mountain range within the warning area to test new precipitation monitoring concepts and refinement of rainfall thresholds for issuance of debris flow warnings.

Debris flow forecast/warning and research activities began in the winter of 2005-2006. The NWS Los Angeles and San Diego WFO's issued debris flow watch and warning statements for recently burned areas using rainfall-duration threshold criteria developed by USGS geologists. The Verdugo Hills region (partially burned from the 2005 Harvard fire) near Burbank, CA, was selected for the IRA for the first winter. NOAA/NSSL operated a SMART-R scanning precipitation research radar at Burbank in January-March 2006 and NOAA/ESRL installed a 915-MHz wind profiler/RASS/surface-met/GPS-precipitatble-water-vapor system at nearby San Fernando in late January 2006, which will continue to operate through mid-2006. Five winter storms, including two heavy rain events, were monitored by the SMART-R radar. One storm (1JAN06) produced a significant debris flow in the IRA. (The same storm produced a debris flow on Interstate 80 in the HMT study area). Data are now being processed from the first winter's observations.

Problems:
1) Projected initial funding for the debris flow work in the IRA was very meager and its continuation is uncertain. The initial projected funding, barely adequate for data collection, will not support much in-depth analysis.
2) The same NOAA groups responsible for the radar observations in the debris flow IRA are also heavily committed to simultaneous field observation work 400 miles farther north in HMT. This created logistics and manpower stress for both projects. Fortunately, no significant storms were missed in the 2005-2006 winter by either project.

Comments/Questions associated with **Debris Flow Report**

- There was a question about the possibility of Debris Flow activities during the 2006-2007 cool/wet season. It is unclear at present whether Debris Flow data collection will occur during the upcoming cool/wet season. Factors that may affect decision are the number and location of fires that occur in So. Cal. and development of funding to support data collection.
- There will only be one SMART-R available during the upcoming cool/wet season. If funds for deployment of gap-filling radars are identified for this upcoming cool/wet season, this will make it difficult to support QPE needs for both HMT-West and a So. Cal Debris Flow field activity.

3. QPF Verification Issues

There are potentially two times scales and at least two if not more options for QPF verification methods for HMT West. Since the HMT has as its focus the day 1-2 time frame and since it is heavily focused on observation platforms and their impact on forecast improvement it is necessary to separate the times scales and the focus of the verification systems.

0-12 hrs - The Nowcast as it were is much more dependent on forecaster understanding/interpretation of real-time observations and how these can be converted into a QPF. Most if not all forecasters within the NWS do not have a working concept of quantifying the information from these observations into a meaningful QPF. There are currently no decision support tools other than something like the Rhea model that can convert low level winds and moisture information combined with radar and satellite data to compute condensate supply over a given topographic region to produce useable QPF for the CNRFC. Thus one outcome of the current HMT is to develop a decision support system that will provide the forecaster with short-term real-time potentially 1, 3 and 6-hr QPFs during the first 12 hrs of the forecast cycle that can be updated frequently. Not only will this provide a legacy system for the HMT but if developed early on can be verified and calibrated (bias corrected) before the end of the project.

6-48 hrs – Numerical guidance is fundamental to the issuance of QPF at these time periods. Since this program has direct hydro applications it is critical that the QPF be accurate over the basin being studied. It is proposed that the current NPVU verification methodology (Charba et al , 2003), be adapted by the HMT, but for the individual basins defined by the project. This might include the South Fork Yuba, the North, Middle, and South Forks of the American, as well as the Truckee. This will allow an assessment of any north-south displacement of model guidance that might be occurring as well as downwind assessments. A grid mask can be applied to the current CNRFC NPVU grid to extract the various basin information for the current NPVU models suites that is being stored on the 4 km HRAP grid at NCEP. All model data being run by ESRL/GSD would be made available in grib in 6-hr, 24- hr and storm total amounts so that verification statistics and comparison graphics (Fig. 1 but for 4 km over west slopes Sierra versus entire CNRFC domain) are made available within 24-hrs of an IOP being completed (www.hpc.ncep.noaa.gov/npvu) . The benefit of the various time scales is to assess any lead or lag temporal errors and to possibly asses how well the water budget of the basins are being handled.

From a modeling perspective it is clear that output from the models using various data denial schemes and various physical parameterizations will help assess the model forecasts. If we use as a standard the 6-hr time period and the NPVU software we will have a baseline to compare from. Consider this a first step. It is suggested that ESRL/GSD port the software from the NPVU to Boulder, have access to the gridded information stored at NCEP, and run daily verification for 6 and 24 hr time periods. The QPE used at NCEP, based on the CNRFC MM methodology, should be compared to the QPE efforts of the HMT (QPESUMS?). QPF verification should emphasize the heavier 6-hr amounts such as .5 and 1 inch values to highlight the more hydrologically significant amounts. See Fig. 1 below. A second step would be to begin a serious evaluation of the ensemble of QPFs available and begin to formulate a more probabilistic verification approach. The HMT must begin to address this and would support the conclusions reached in the USWRP Cool Season QPF summary document (Rauber and Ralph, 2004).

It is also suggested that ESRL/GSD post graphics on the HMT web site in a form similar to the comparison graphics in Figure 2 (but for 4 km HRAP grid not 32 km)using the domain covered by the ESRL/GSD models. These would be 6-hr and 24 hr summary graphics posted as soon as possible after model completion. Products will be fed through external product interface into AWIPS or ALPS running at the SAC WFO and/or CNRFC (See Table 1 below).

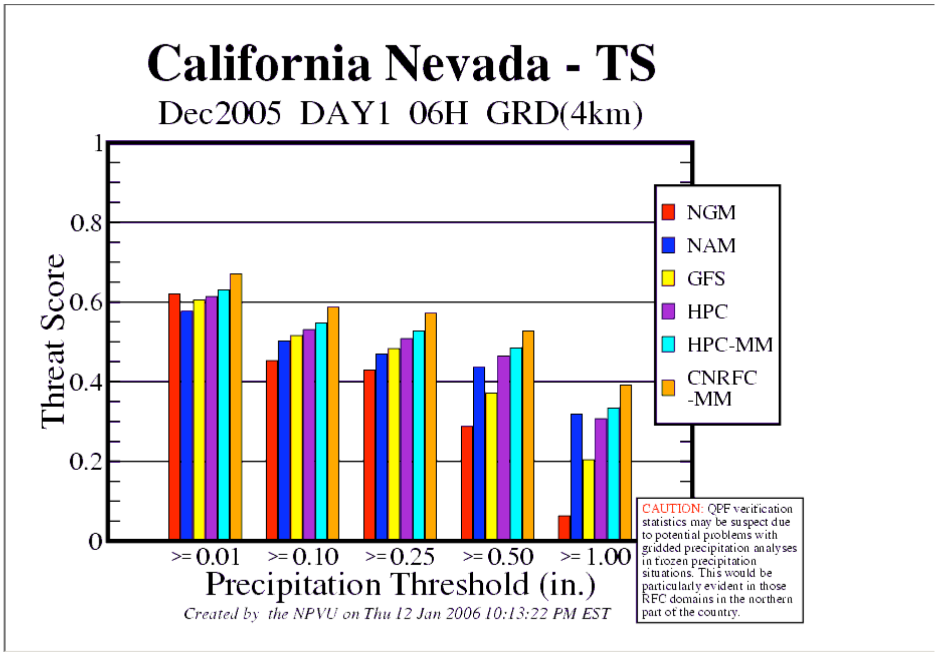

Figure 1 NPVU categorical statistics for CNRFC for December 2005. Similar statistics should be performed but for the individual basins noted in text.

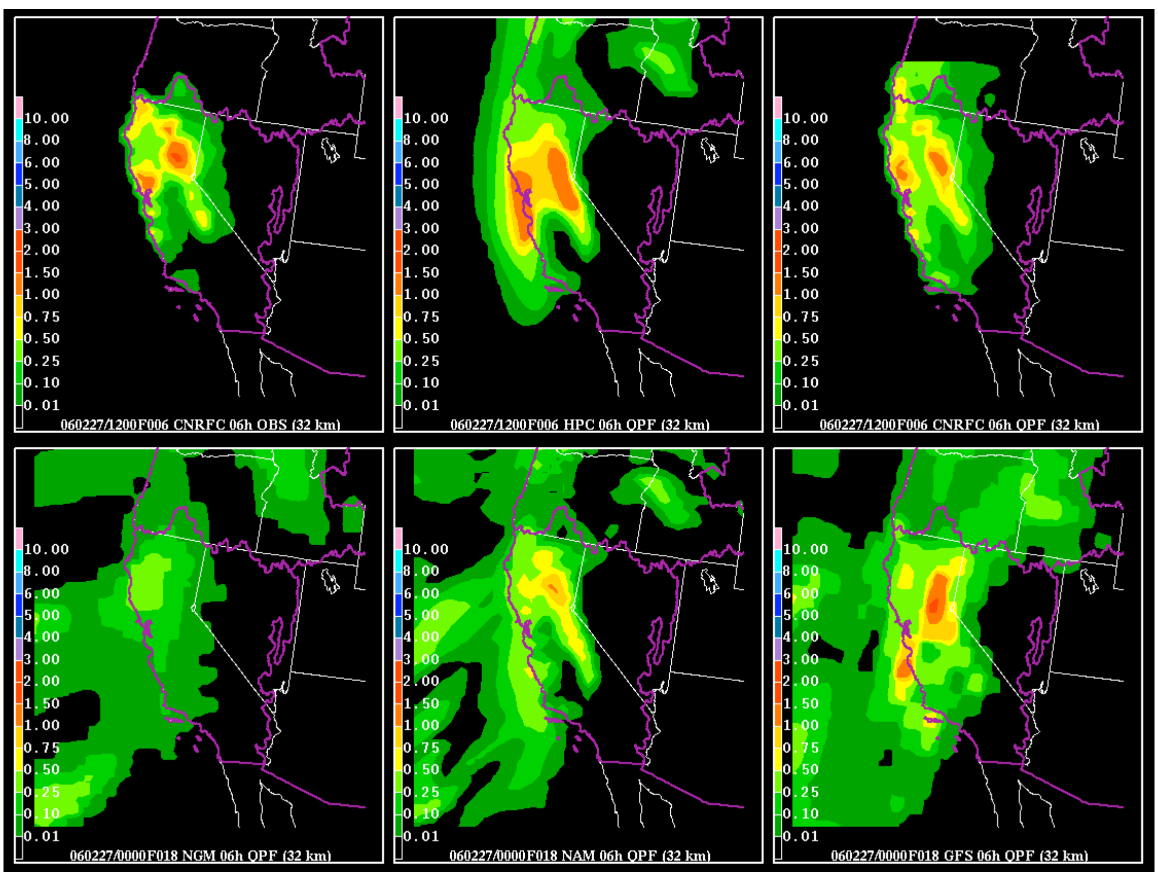

Figure 2 Comparison graphics noting CNRFC forecast along with model uidance available for entire CNRFC domain. Suggested that HMT produce similar graphic but utilizing 4 km HRAP grid over the domain of the ESRL/GSD model.

Table 1 HMT 06-07 ESRL/GSD ensemble verification proposal

1. Run an ensemble at 3-km resolution. The ensemble will be optimized on the basis of the work by Jankov, et al, 2006.
2. Forecasts will be provided in the following proposed configurations and formats (pending discussions with forecasters at the sites above)
    a. Spaghetti diagrams (contours for all members) for critical precipitation thresholds for 6 hr accumulations (out to 24 hrs): 0.1, 0.5, 1.0 inch
    b. Ensemble mean
    c. Ensemble upper quartile
    d. Ensemble lower quartile
    e. Debiased and normalized probabilities for 0.1, 0.5, 1.0 inch for 6 hours
    f. "   0.5, 1.0, 1.5, 2.0 for 24 hrs
    g. point precipitation forecasts at gauge sites for input into schemes like Mountain Mapper
3. Real time verification
    a. Set up and run the NPVU categorical statistics generator at GSD
    b. Generate Threat scores for 6h, 24 hr forecasts (previous cycle)
    c. ETS scores
    d. Briar, BSS, ROC scores

Charba, J, D. Reynolds, B. McDonald and G. Carter, 2003: Comparative Verification of Recent Quantitative Precipitation Forecasts in the NWS: A Simple Approach for Scoring Forecast Accuray. *Wea. and Forecasting*, **18,** 161-183.

Rauber, R. M., F. M. Ralph and others, 2004: Improving Short-Term (0-48 hr) Cool Season Quantitative Precipitation Forecasting. Recommendations from a USWRP Workshop. *Bull. Amer. Meteor. Soc.*, **86,** 1619–1632.

Comments/Questions associated with **QPF Verification Issues**

- There are varied opinions on the utility of 0-12 h diagnostic nowcasting tools like the Rhea model. A few participants feel that it will be difficult for such a tool to outperform deterministic/probabilistic numerical weather prediction. However, there were equally strong opinions that expressed doubts about this assertion. This dichotomy of thinking suggests that a comparative evaluation of the two approaches is needed.
- There was a question as to who should take the lead in NPVU-type verification: ESRL/GSD or the NPVU. There was a suggestion that a request into the Office of Climate, Weather and Water Services (OCWWS) may allow the NPVU to take the lead in this area.
- The top QPF priority is to get high resolution model output (both deterministic and probabilistic) to forecasters via AWIPS and/or ALPS workstations
- There was a suggestion that the concept of Distributed Local Modeling (DLM) should be explored. DLM would allow a WFO or RFC to have a basin-focused NWP (deterministic and probabilistic) effort during critical events. Impact assessments in the context of HMT would be essential.

- There was a suggestion that development of probabilistic verification in the NPVU should be made a high priority
- There were comments that Q2 QPE output will be critical for validation of the high-resolution simulations and 0-12 h nowcasting diagnostics generated during/after HMT-West 2006 and for future HMT-West field deployments. It was also mentioned that assimilation of the XPOL and SMART-R QPE into Q2 will be important related activities to be undertaken.

4. Streamflow Verification Issues

Mike Smith and Eric Strem
June 12, 2006

Significant knowledge gaps exist in mountainous area hydrology. Among the major questions for hydrologic modeling for river forecasting are:

1. What is the required 'network density' needed to improve our hydrologic simulations?
2. What improvements can be achieved with better hydrologic models?

Increasingly in this era of budget constraints, we must determine the end-to-end impacts of improved observations and models. In other words, how much improvement in our current river simulation and forecasts can be achieved with observations from new sensors?

We propose to assess the value of advanced HMT observations to streamflow simulation and forecasting via rigorous analysis of simulations with and without the HMT data as shown in Figure 1. We propose first an analysis of retrospective streamflow simulations rather than forecast streamflow. In this framework, we generate hydrologic model inputs using the current data sources of surface gage observations of precipitation and temperature, etc. These observations are converted into time series of model forcings. The precipitation-runoff models ingest these forcings to generate retrospective streamflow simulations as the 'standard of comparison'. The NWS CNRFC models will be used here. These can be compared to observed USGS flow observations.

As shown in Figure 1, we then process the HMT observations to create 'HMT improved' time series of the same hydrologic model forcings. These value added forcings are used with the same precipitation-runoff models to generate HMT-enhanced streamflow simulations. These simulations can be compared to USGS observed flow and the 'standard of comparison' developed earlier. These statistical analyses should determine the value of the HMT data to RFC river simulation.

We propose that the analysis of HMT observations be performed in concert with the second phase of the Distributed Hydrologic Model Intercomparison Project (DMIP 2). DMIP 2 allows us to analyze the HMT observations with multiple cutting-edge models and not just the NWS lumped and distributed models. We believe a multi-model analysis of the HMT data will add great weight to the conclusions regarding the value of the HMT data.

Future work should include using the HMT observations and models in a 'forecast' experiment to complement the retrospective simulation experiments described above. Here, the HMT observations are used to improve the numerical weather prediction models to provide improved QPF and QTF forcings for the precipitation-runoff models. Forecast experiments help determine the lead time during which improvements have any effect.

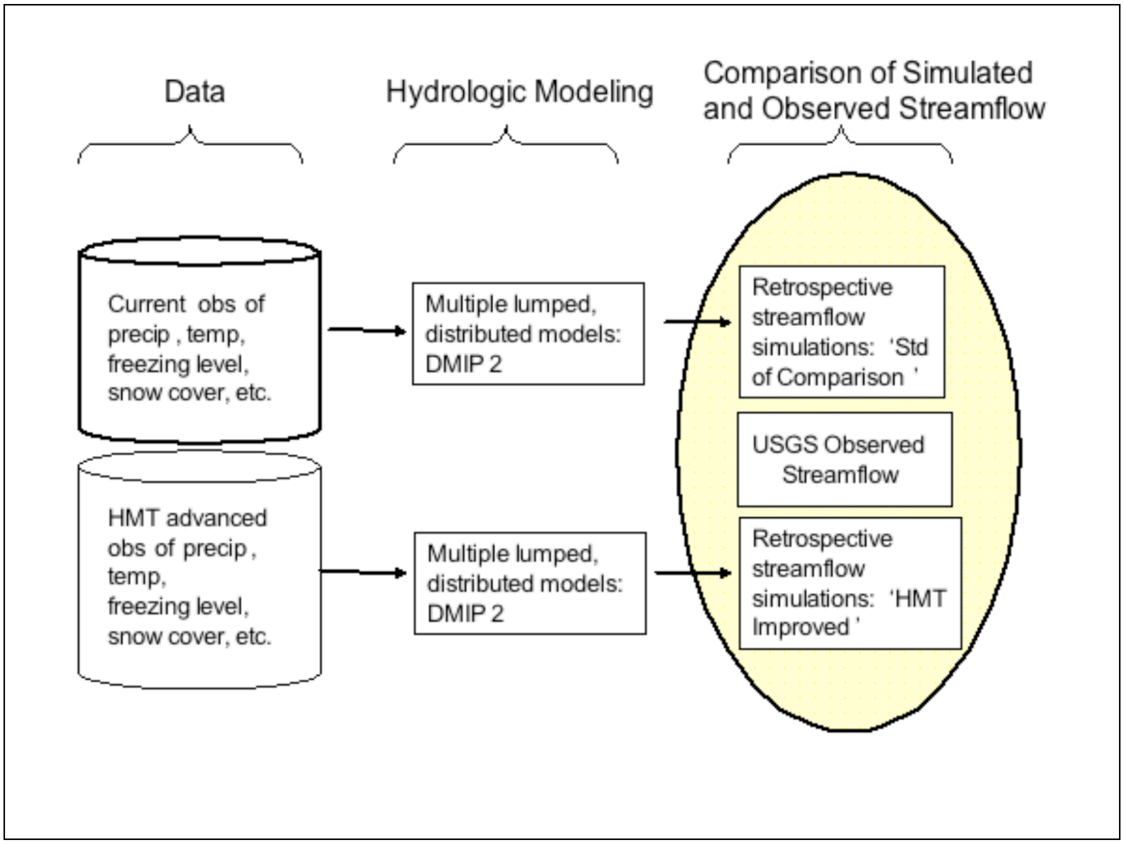

Figure 3. Framework for assessing the value of HMT observations to NWS river forecasting

Comments/Questions associated with **Streamflow Verification Issues**

- There was a comment that the more detailed nature of distributed models calls for a more detailed verification strategy compared to verification of lumped models.
- There was a discussion as to how the HMT observations would be converted to gridded fields and 'inserted' into the baseline precipitation and temperature gridded time series for DMIP 2.
- There was a comment regarding the need for additional streamflow sensors to more comprehensively monitor streamflow for verification purposes.

5. Experimental Design / Research to Operations Issues

Background: This document describes science priorities and experimental design for future HMT – West efforts focusing on 2006-2007.

Science Priorities (no particular priority):

1. Extension to east side of Sierra Nevada into Truckee River basin. Forecasts have historically struggled with the significant "lee side" precipitation events. There is a desire to develop a better

conceptual model of how the storms interact with the whole mountain environment and its impact on the distribution of precipitation

2. Improve snow level and amount estimation in data sparse areas, especially above 5,000 feet. Forecasters do not have a high degree of confidences using the current observation platforms and analysis tools for the distribution of precipitation amounts above 5,000 feet where precipitation tends to be snow.

3. Improve QPE

4. Improve QPF

Proposed Experiments (no particular priority)

Common Elements to all Experiments:

- Design HMT experiments to address specific science/operations questions to improve understanding of hydrologic and meteorology processes and to improve NWS service programs.
- New methodology / applications must be compared to current NWS baseline.
  - Comparison must asses improvement over baseline
  - Comparison ensures research – operations process by tying research activities to operational baseline
  - New methodology should first be validated to some extent in lab setting (rather than real time NWS operational setting) before potential NWS real time evaluation.
  - Once validated, new methodology should be applied in real time operational forecast environment. This should include assistance in applying methodology correctly.
- Experiments should yield results applicable to other western river basins.

1. **Science Experiment #1: Fundamental Improvement of baseline hydrologic forecasts through improvement to observed (and analyzed) and forecast forcing fields. The forcing fields for hydrologic forecasts include precipitation, temperature, and freezing level.**
   a. Baseline forecast and analysis grids to be defined by NWS
   b. Interface with DMIP2 to ensure data meets DMIP2 requirements and to test new forcing fields with new hydrologic models
   c. How will improvements be measured over the baseline grids? Are we measuring the current baseline grid performance correctly?
   d. Can new observing systems improve analysis grids? Forecast grids? Where? How much?
   e. Can new numerical weather models (WRF, others) improve these grids? Where? How much?
   f. Can new (precipitation) analysis schemes improve analysis grids? Where? How much?

g. This set of experiments could be conducted on HMT-2005-2006 domain (lower N Fork American Basin) with no new or continuing field activities.
h. DESIRED OUTCOME: Improve analysis grid by X %? Improve forecast grid by Y%? Improve hydrologic forecast by Z%? Improve Flash Flood warnings(?); Case oriented (cases selection coordinated w/ NWS)

2. Science Experiment #2: Improved Conceptual Model of data sparse (e.g. middle elevation N Fork American) and/or poorly understood areas (e.g. lee side, spill over events).

a. Retrospective analysis of past events to quantify error sources both geographically and in hydrologic forecasts based on flood / no flood events (flood stage important for NWS service). Use analysis results to design field experiments where experimental sensors fill gaps identified in retrospective analysis.
b. Adjust new or continuing field development of observation platforms to better capture critical flow/micro-physics that impact lee-side events. The Truckee River basin was identified in 2005 as a potential test basin.
c. Develop criteria to test expected improvement in forecasting lee-side spill over events
d. Adjust new or continuing field deployments to data sparse areas to improve analysis and understanding of data sparse areas (e.g. mid level or other traditionally data poor areas) - areas to be identified by HMT advisory committee and/or from retrospective analysis.
e. DESIRED OUTCOME: Same as experiment #1; Increase POD for floods forecasts

3. Science Experiment #3: Numerical Weather Model Evaluation

a. Some overlap with #1 and #2 above
b. WRF and other new models offer an opportunity test performance of models in complex terrain
c. Test model improvements resulting from inclusion of supplemental data from HMT field experiments
d. Provide forecasters with diagnostics model verification to help offices more intelligently use new models

Comments/Questions associated with **Experimental Design / Research to Operations Issues**

- There was a comment that the research-to-operations opportunities for the ARB are relatively limited, aside from melting level detection. Research-to-operations opportunities might be larger in other adjacent basins (e.g., Yuba, Feather, Truckee) that do not empty into a large reservoir like Folsom. However, there was an alternative view expressed that contradicted this assertion. During major flooding Folsom is not "big enough". The flood encroachment level is about 540k ac-ft. This would allow about another 400 ac-ft max before the dam would overtop. During 1986 there was more than a million ac-ft that ran off into Folsom. Nearly three times the storage available. Therefore, accurate predictions of precipitation and the associated pre-releases that they might trigger are a critical way to protect Sacramento from the New Orleans scenario. The key forecast time scale for the pre-releases is on the order of 5-10 days, which falls outside of the relatively short-term focus of HMT. However, shorter-term, higher resolution forecasts of precipitation also have applicability to a major flooding scenario and the decisions that need to be made by end-users of the information

(e.g., Which basins will receive the largest amount of precipitation? How will the snow level evolve? When will the precipitation event end?)

- There was a comment that the research-to-operations path may be longer than one season.
- Discussions during the meeting indicated that the biggest gap for QPE is radar QPE in the upper part of the NFARB and in the lee of the Sierra crest (Truckee basin favored by WFO's and CNRFC whereas Carson basin selected by DMIP-2). DMIP-2 and the CNFRC are in great need of improved QPE, especially in the upper NFARB.
- Discussions during the meeting indicated that the biggest gap for QPF is validation; primarily precipitation, but also winds and microphysics. Scanning radar derived QPE will be an important component in addressing this gap. However, there is also some interest in data denial experiments to assess impact of assimilating HMT data.
- The difficulties of siting truck or trailer mounted scanning radars in the upper part of the NFARB were discussed. Blockage by trees is the biggest factor that limits site options. The southern end of the Blue Canyon airport is perhaps an option that can be explored. Further discussions with the appropriate authorities are recommended. Mounting the radars on towers (like the CASA "cell-phone-tower" radars) would probably overcome some of these problems. A test of a CASA radar in the ARB may occur during one of the next few field seasons.
- Discussions during the meeting indicated that the secondary observational priority is to better map snow level in the upper part of the NFARB and in the lee using profilers, disdrometers, and micro-temperature sensors. It was suggested that CALTRANS logs could also be used as a resource to track snow level.
- Opinions were expressed during the meeting that it might be best to execute a very limited field deployment during HMT-West 2007 so that more progress on analysis of HMT-West 2006 data could be accomplished, particularly from the QPE standpoint. However, there was some concern raised that the QPE data collected during HMT-West 2006 will not meet the needs of DMIP-2, thus casting doubts about whether it is worth focusing a great deal of time on its analysis.
- Discussions during the meeting indicated that the fate of SHARE (Sierra Hydrometeorology and Atmospheric River Experiment) may factor in to the decision of how to approach the HMT-West field deployments over the next couple of years. SHARE is an ideal project to pursue the "whole-mountain" research concept described in the Experimental Design white paper. If SHARE will happen in 2007-2008, then it was agreed that delaying microphysically oriented activities to that year would likely be the best approach. However, if SHARE is delayed or cancelled, that approach will need to be re-examined.

6. HMT Mesonet Issues

June 5, 2006

Recommended Installations for American River Basin HMT Mesonet: Phase I

HMT-Mesonet Planning team: Dave Reynolds (co-lead), Jessica Lundquist (co-lead), Dennis Lettenmaier, Eric Strem, Pedro Restrepo, Kelly Redmond, Roger Bales, Don Cline

30 June 2006

HMT-Observing System Co-Leads and ST&I Water Resources R&D Capability Co-leads: Dave Kingsmill and Dave Jorgensen

Motivation and Overview:

A strong backbone of surface observations are needed for ground-truthing and hydrologic model testing in the HMT and DMIP2 projects in the North Fork American River Basin in California. Approximately $30,000 has been allocated for the purchase of such equipment. Because HMT is already in progress, action needs to be taken quickly. Phase I items are installations that should require little thought and debate. These are initial purchases and installs for Summer/Fall 2006, while further installations will require additional planning. For future planning, we hope for $30,000 more in fiscal year 2007.

HMT seeks to balance measurements made for basic science and for operations. The HMT Mesonet advisory group agrees that measurements are needed most in the snow zone. Because of the generous participation of a wide-variety of universities, research centers, and government agencies, we will be able to make a little money go a long way while strengthening partnerships and collaboration.

How (who, what, where):

1. Science Enhancements at Onion Creek

Kelly Redmond and the WRCC installed a weather station at Onion Creek (Figure 1) with telemetry and a snow depth sensor but no precipitation measurements, due to the unavailability of power or heat. This is near a shielded precipitation gage with a paper trace that is maintained by Randall Osterhuber of the Central Sierra Snow Lab, which provides a historical record but no real-time data. We propose <u>enhancing this station with an ETI weighing gage</u>, which can operate under these conditions. Installation will be conducted by Dave Simeral of the WRCC, and data will be available in real time from their website. Roger Bales of UC Merced will donate a cluster of 5 to 6 Judd snow depth sensors to test the spatial variability of snow accumulation in this region and one soil moisture sensor. These will be installed by Roger Bales and Bob Rice of UC Merced. This will tie in with stream-depth sensors in the vicinity installed by Jim Kirchner of UC Berkeley. Eric Strem of the NWS-CNRFC recommended a high-quality precipitation gage in the snow zone as the most potentially useful for operations. Dennis Lettenmaier of the University of Washington recommended distributed sensors as most useful for research. All of these measurements will be available for hydrologic modelers participating in DMIP2.

2. Precipitation Gauge Comparison

To test how well the ETI gage compares with heated gages and laser disdrometers and to characterize when corrections may need to be made to various gage measurements, we propose installing <u>one ETI weighing gage at the Central Sierra Snow Lab</u>. This site already has a heated weighing precipitation gage (Geonor) installed by the WRCC, and NOAA will install a laser disdrometer there for evaluation in winter 2006-07. If the WRCC does not install a hot plat precipitation sensor there this summer, NOAA will need to install one. The site has a full-time manager, Randall Osterhuber, who can aid with repairing potential mid-winter malfunctions. This instrument would be installed by NOAA with the coordination of the WRCC and Randall. This would further enhance our ability to interpret precipitation measurements within the snow zone, a priority expressed by Eric Strem.

3. Precipitation Gauge at the best "bang-for-the-buck" SCPP site

Tsintikidis et al. (2002) examined the network of precipitation gauges used in the SCPP (Reynolds and Dennis, 1986) experiment and statistically determined which of these would be the best possible places to install new permanent gauges for the American River Watershed as a whole. Dave Reynolds selected Sunflower Hill from these recommended sites, based on 1) its proximity to the NF American River, 2) its location in a currently unsampled region of the watershed, and 3) its location in the zone of maximum precipitation for the entire watershed. Sunflower Hill is near Duncan Hill, an existing RAWS site which does not require additional Forest Service permitting and already has telemetry. Therefore, we will install the gage at Duncan Hill.

Table 1: Locations of Sunflower and Duncan Hill

Name	Longitude	Latitude	Elevation (m)
Sunflower Hill	120.4591667	39.16527778	2091
Duncan Hill	120.509	39.144	2164

Dave Reynolds recommends using ETI gages, the same brand of gauges used in SCPP. These are 50-gallon drum weighting gages that weigh the entire bucket (including any snow sticking to the side) with ethanol antifreeze with a drain and fill system.

4. Snow Depth Sensors at existing CA DWR snow pillows

To make predictions during rain-on-snow storms, understanding temporal changes in snow density is crucial (Steve Goldstein, NWS, personal communication). Right now, only a few of the CA DWR snow pillows in the region have co-located snow depth sensors. Adding snow depth sensors to existing sites would allow us to utilize infrastructure (solar panels, data logger, telemetry) that is already in place. Additionally, the CA DWR snow surveys will install and maintain the instruments without charging NOAA (Frank Gehrke, personal communication). We recommend purchasing Judd snow depth sensors (recommended by Kelly Redmond, WRCC) and installing them at the following sites. The sites were chosen on the criteria of 1) proximity to the North Fork of the American, 2) desire to have an elevational transect of density, and 3) use of the SMUD-type rubber snowpillow, which responds more quickly to snow changes than the metal snowpillows used in most of the region.

Table 2: Locations of snowpillows to enhance with snow depth sensors

name	ID	elev(ft)	lat	lon	county	government agency in charge
HUYSINK	HYS	6600	39.282	120.527	PLACER	US Bureau of Reclamation
GREEK STORE	GKS	5600	39.075	120.558	PLACER	US Bureau of Reclamation
MEADOWLAKE	MDW	7200	39.417	120.508		CA Dept Water Resources
ROBBS SADDLE	RBB	5900	38.912	120.378	EL DORADO	SMUD
ROBBS POWERHOUSE	RBP	5150	38.903	120.375	EL DORADO	SMUD
ALPHA (SMUD)	ALP	7600	38.805	120.215	EL DORADO	SMUD
VAN VLEC	VVL	6700	38.945	120.305	EL DORADO	SMUD
LAKE LOIS	LOS	8600	38.925	120.197		CA Dept Water Resources

Costs:

Precip Stations			
ETI gages	$6345 each	x3	$19,035
Telemetry	already available		
Installation and Maintenance (handled by NOAA/HMT engineers)			
Judd Snow depth Sensors	$550 each	x8	$4,400
Telemetry	already available		
Installation and Maintenance:	provided by CA DWR		
Total			$23,435

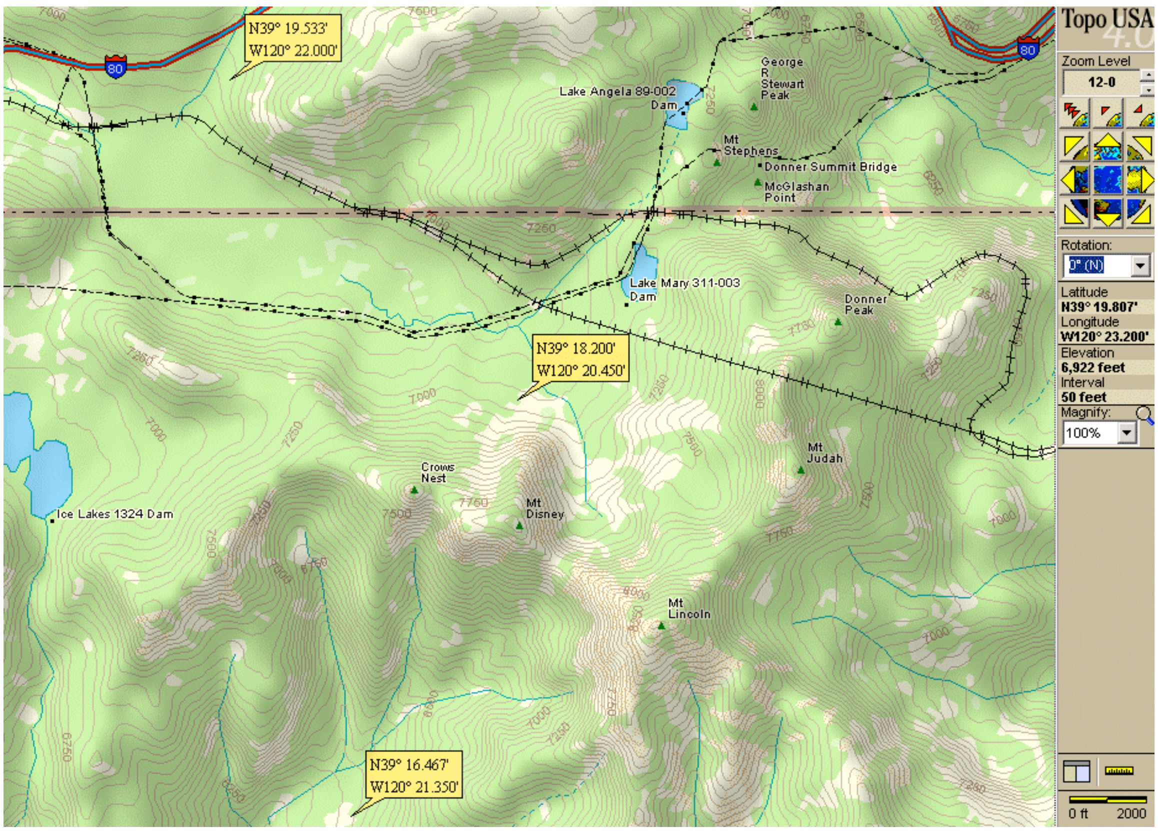

Figure 4 Map of the Onion Creek weather station (most southern yellow latitude and longitude marker).

Comments/Questions associated with **HMT Mesonet Issues**

- There was a comment that the term "HMT-Mesonet" in the context of this discussion is somewhat misleading, since the instruments discussed can more accurately be described as augmentations to an existing network (research and operational) of surface instrumentation. Therefore, the term "HMT-Mesonet Augmentation" may be more appropriate.
- There was a suggestion to deploy lots of inexpensive recording temperature sensors throughout the basin to monitor snow level, among other things.

7. HMT Outreach Ideas

Outreach activities in association with HMT are required in several areas. HMT needs more managerial oversight of project planning, coordination and execution than a traditional scientific field experiment given its mandate to focus on transition of research to operations. Therefore, outreach between the research and operational communities associated with HMT is critical to achieving HMT objectives. Coordination between these groups will be needed to insure that each NOAA component of the effort understands their role and executes their part of the project at the appropriate time and within available resources. Occasional workshops involving both communities are one way that this outreach may be manifested. Other forms of this outreach could involve research scientists participating in forecast shift operations during HMT IOP's and operational forecasters visiting research laboratories during the off season to participate in analysis of HMT datasets.

There will also need to be HMT outreach with the NOAA Matrix Programs that make decisions on funding. HMT has the potential to become a large, well-funded program, through a combination of sponsors. But most of the big dollars are in the "proposed" stage of out-year budgets. As was learned painfully in the last two budget cycles, that funding is vulnerable. Vigorous outreach with the relevant NOAA Matrix Programs (ST&I, HYD, LFW, EMP among others) is necessary to minimize the HMT funding vulnerability. The evaporation of the large future proposed funding would render a diminished program with much less chance for reaching its ambitious goals.

Linkages with the public and other key end-users are another critical element of HMT outreach. For example, the HMT-West project provides several unique outreach opportunities at the local National Weather Service Weather Forecast Office (WFO) level. In order to reach the greatest number of our customers, local broadcast and print media outlets should be utilized. Simple additions to existing outreach materials would also aid in the education of our customers to this project. Finally, it may prove beneficial to incorporate the local teaching community into HMT-West.

By utilizing existing relationships with local media personalities, the HMT-West project can attain the most widespread exposure. The Sacramento Bee frequently focuses on weather-related issues for feature length stories. It is assumed they would show similar interest in an HMT story. The television broadcast media is rather unique in the Sacramento region in that nearly every network has a crew that provides live broadcasts from the Sierra during winter storms. Perhaps a field trip could be arranged for these weather crews to observe some of the HMT instrumentation while in an operational mode.

The Sacramento WFO maintains a wide spectrum of outreach projects throughout the year. We have already begun adding a basic HMT overview to some of our presentation material. Additional outreach material, such as pamphlets or basic slide sets, could be utilized to target specific groups that might benefit from the HMT project.

It has also been suggested that by incorporating area teachers into the outreach effort the work of the HMT project could be extended into the schools. Teachers could be invited to the WFO for a “train the trainer” sort of experience. Materials that could be utilized in the classroom should be developed and provided for participants. By targeting high school and college level students, we could also provide an environment rich in shared research opportunities.

Comments/Questions associated with **HMT Outreach Ideas**

- There was a suggestion to initiate a student data analysis program or expand the existing student data collection program to include data analysis
- There was a suggestion to develop a free-standing panel or poster compatible with planned NWS panels to advertise HMT activities at meetings
- There was a suggestion to make outreach efforts to other related science areas such as water quality
- There was a suggestion to focus outreach toward potential customers of improved snow forecasts / analyses and / or lee side forecasts.