Investigating the Feasibility of Incorporating Remote Sensing into Existing Frameworks for Improving Water Supply and Drought Forecasts in California

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Statement of Problem

- **Snowpack critical to water supply in Western U.S.** (e.g. 70-90% of water in Los Angeles comes from snowmelt runoff (Sierras+Colorado River)
- **CA Dept. of Water Resources charged with forecasts of snowmelt runoff from Sierra Basins** (Los Angeles DWP forecasts Owens and Mono basins; Metropolitan Water District interested in both Sierras and Colorado River)
- **Annual value of water from major CA watersheds is ~$3.3 billion, and corresponding value of hydropower is ~$1.3 billion** (with the specific value of the forecasting program estimated at 3-5% of these amounts for a value of $140-230 million; *Roos, 2003*)
- **Forecasts provide first-order inputs to water management decisions downstream, having potential for further economic impact** (especially in drought years)

Statement of Problem

Current Forecasting System:

- Forecasts made for April-July runoff ($AJRO$) on first-of-month (starting Feb.) for each basin
- Regression based on in-situ snow, precipitation, and streamflow data, e.g.:

$$AJRO = C_1(SNOW) + C_2(OMPT) + C_3(AJPT) + C_4(OMRO) + C_5(PYRO) + C_6$$

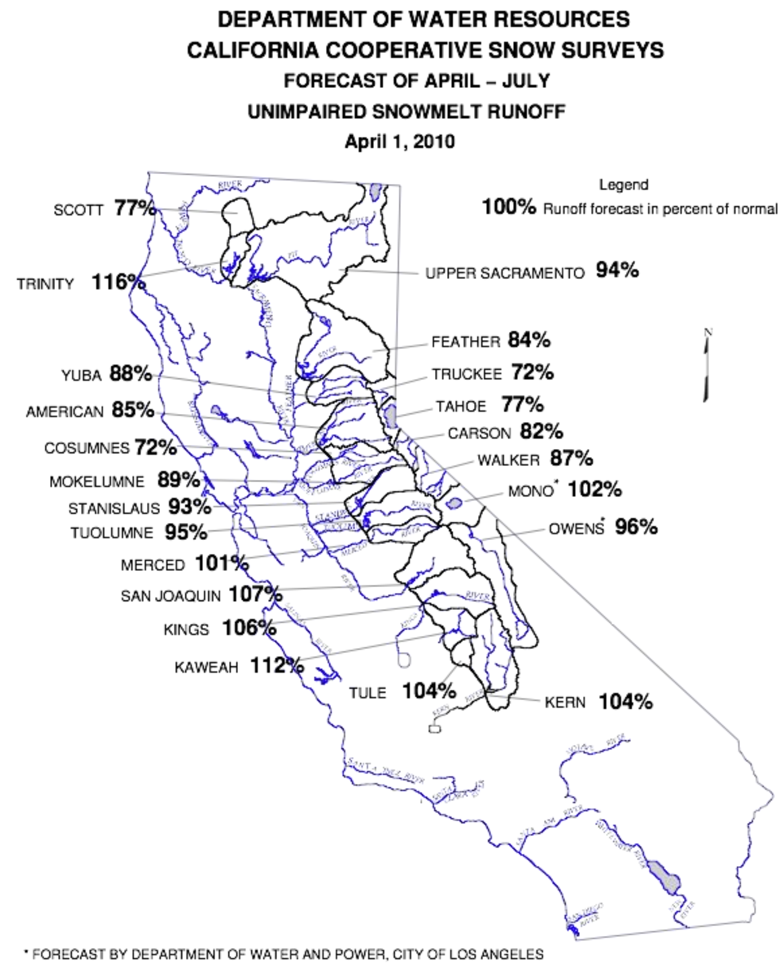
$SNOW$ ° snow index (based on in-situ snow surveys)

$OMPT$ ° October-March precipitation

$AJPT$ ° April-July precipitation

$OMRO$ ° October-March runoff

$PYRO$ ° Prior year April-July runoff



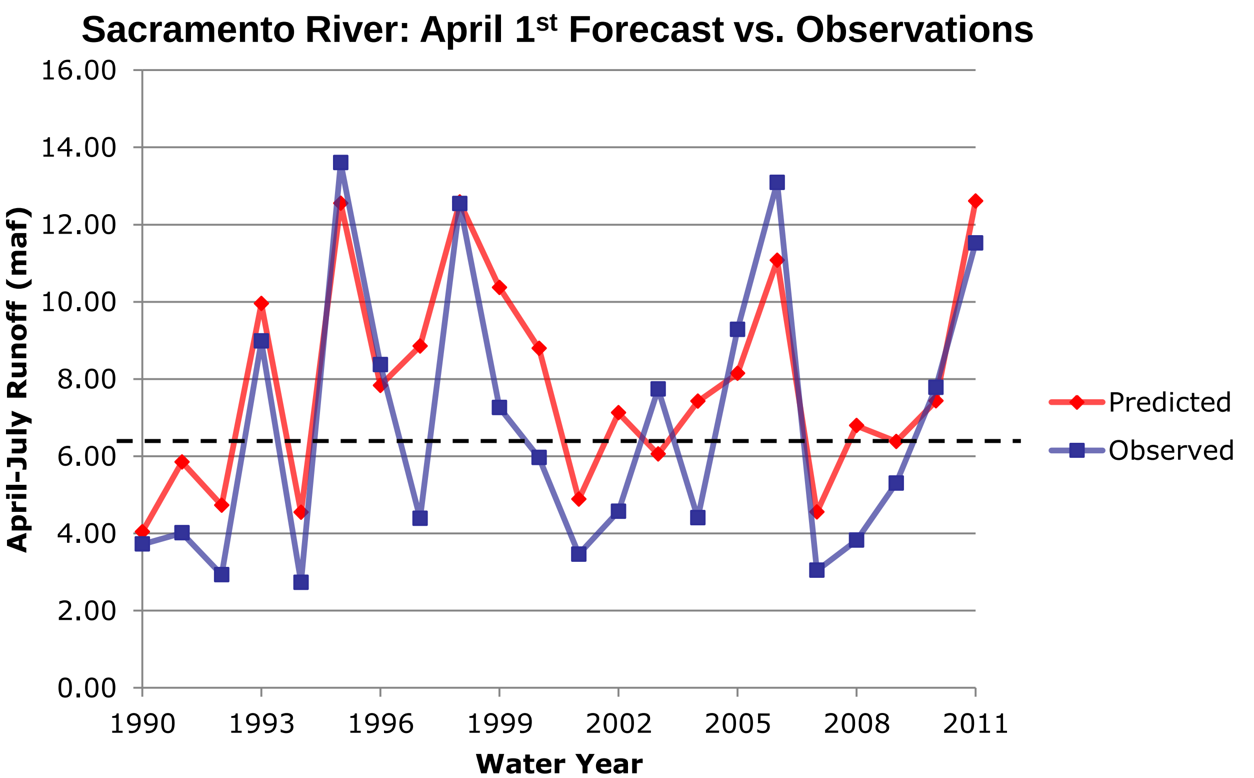
Basic question: To what extent can snow-related remote sensing (and derived products) be used for improving on these forecasts?

Stage 1 Research Questions

- Stage 1 proposes to examine how relatively small modifications to existing framework might improve forecasts; so within the context of existing framework we aim to address:
  - What maximum possible improvement in existing forecast could be expected in dry/drought years?
  - How representative are in-situ snow data of basin-average snow water equivalent (SWE)? How does this vary between dry/wet years; basin physiography; density of in-situ data?
  - Can historical SWE reanalysis using assimilation of satellite-derived snow covered area measurements provide additional insight that can be used in forecast?
  - Can real-time passive microwave measurements add additional predictive capability to forecast?

Potential Improvements in Existing Framework

- **What maximum possible improvement in existing forecast could be expected in dry/drought years?**

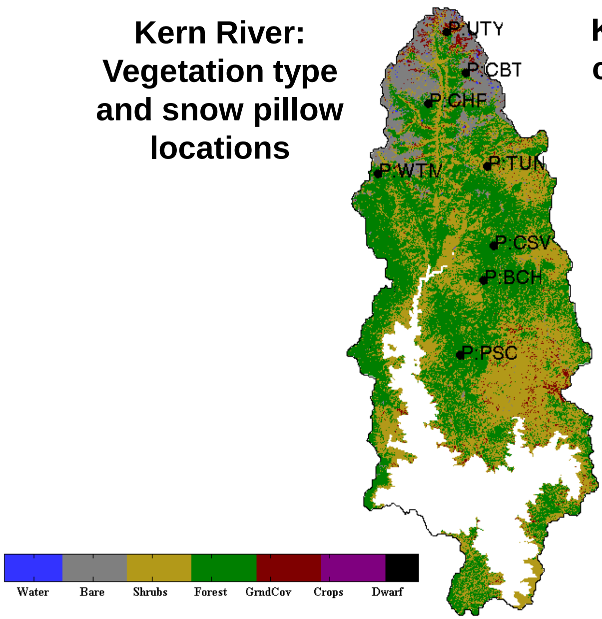


- Percent error for "dry" (5.4-6.5 maf) and "critical" (<5.4 maf) years is often significant.
- Will examine for multiple basins and longer periods to assess and quantify potential for improvement

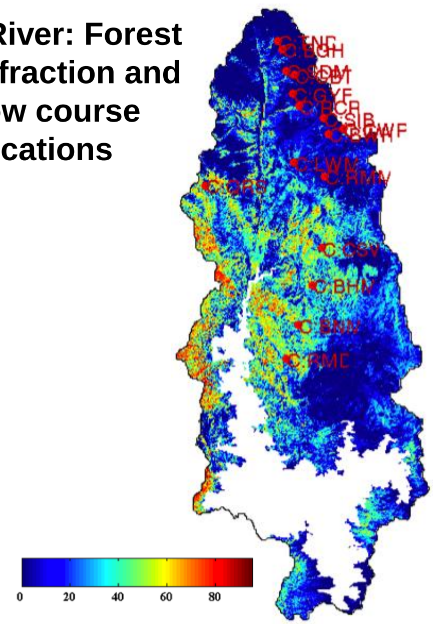
Representativeness of in-situ SWE data

- **How representative are in-situ snow data of basin-average snow water equivalent (SWE)?**

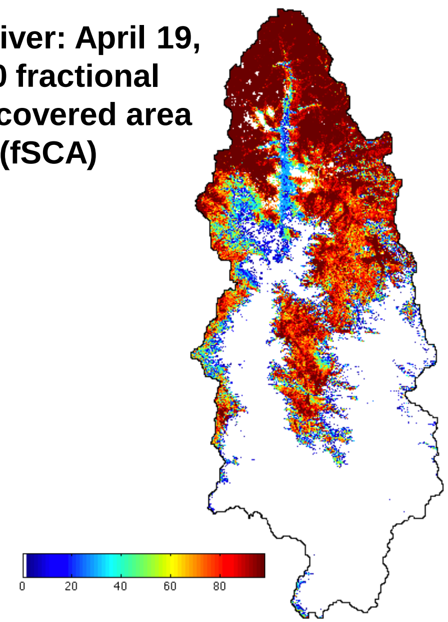
Kern River: Vegetation type and snow pillow locations



Kern River: Forest cover fraction and snow course locations



Kern River: April 19, 2010 fractional snow covered area (fSCA)

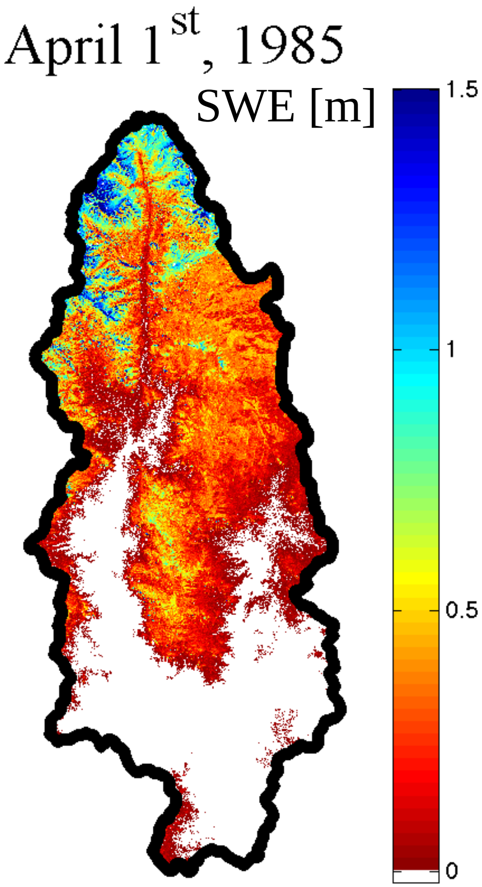


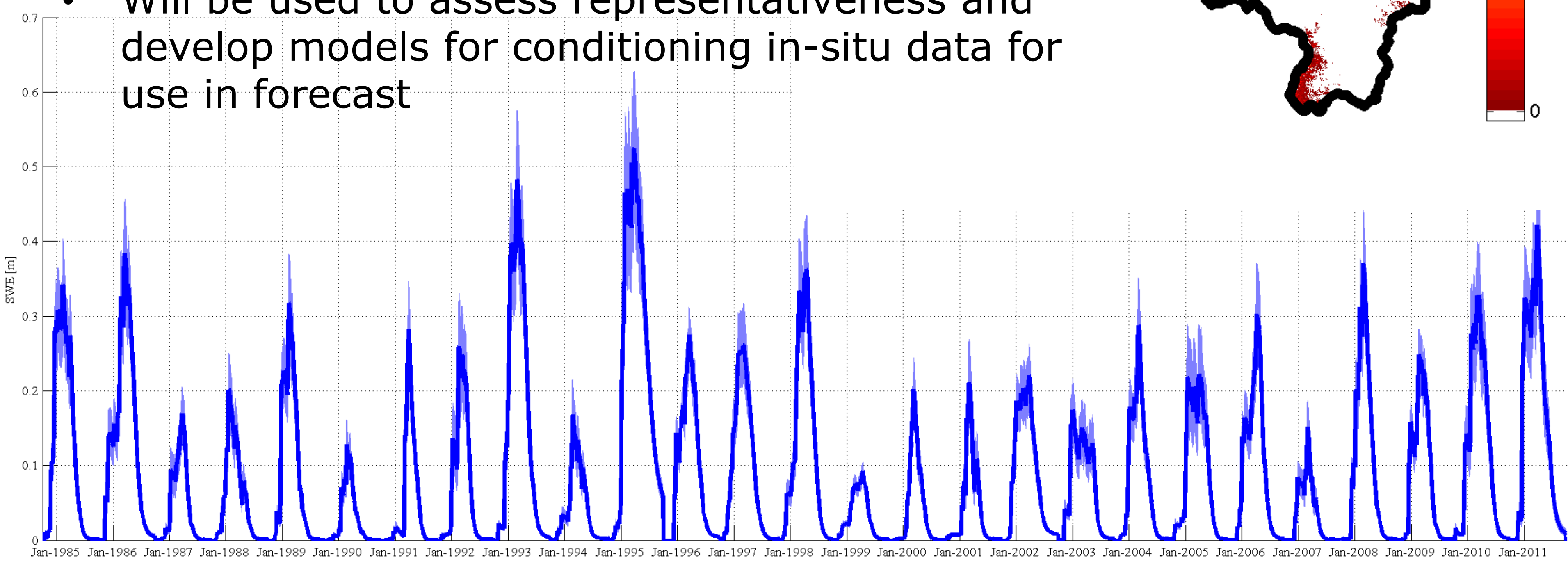
  - Assessment of representativeness requires accurate spatially-distributed SWE estimates to compare against

- Can historical SWE reanalysis using assimilation of satellite-derived fractional snow covered area (fSCA) measurements provide additional insight that can be used in forecast?

Long-term probabilistic SWE reconstruction

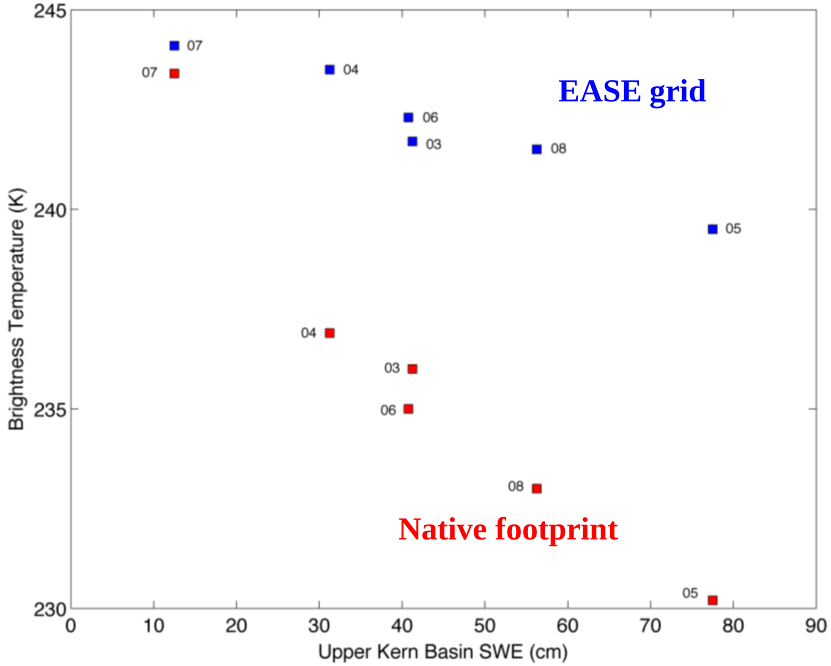
- Plan to use previously developed method/s to generate SWE reanalysis via assimilation of fSCA time series and other remotely sensed/NASA datasets (*Durand et al. 2008*, *Girotto et al., 2012*)
- Preliminary application in Kern over full Landsat 5 record
- Will be used to assess representativeness and develop models for conditioning in-situ data for use in forecast

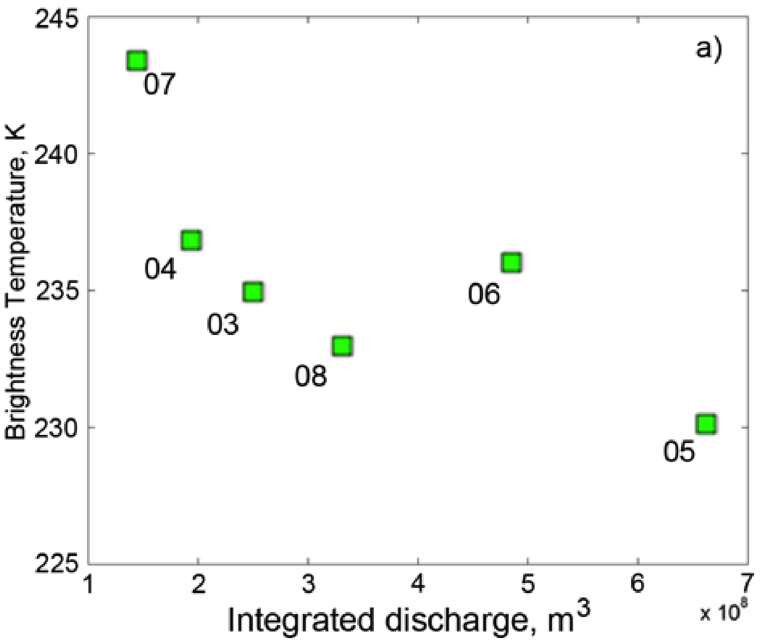




Use of Passive Microwave Data in Forecast

- **Can real-time passive microwave measurements add additional predictive capability to forecast?**
- Recent work (*Li, Durand, Margulis, 2012*) over upper Kern has shown good sensitivity between minimum 36 GHz AMSR-E brightness temperature (i.e. near peak accumulation) and both SWE and integrated runoff





- Hypothesis: PM data may have some predictive forecast utility

Anticipated Impacts

- Stage 1:
  - Thoroughly assess where and to what extent likely improvements in *existing* system can be made (with respect to snow and drought years in particular)
  - Examine representativeness of in situ SWE data in characterizing basin-wide SWE in drought conditions; Propose/test use of results from long-term reanalysis to better condition in-situ data for use in forecasts
  - Propose and test augmented forecast system using: i) results from long-term reanalysis to better condition in-situ data and PM data, e.g.:

$$AJRO = C_1(\mathbf{SNOW}\text{¢}) + C_2(OMPT) + C_3(AJPT) + C_4(OMRO) + C_5(PYRO) + C_6 + C_7(\mathbf{TBMIN})$$

SNOW¢º improved snow index (based on conditioning in-situ data on historical reanalysis)

TBMIN º Minimum brightness temperature up to forecast date (over snow covered portion of basin)

Strategies for Quantifying Impacts

- Quantification of impacts:
  - Impacts will be quantified via application to several test basins throughout Sierras in hindcasting mode with emphasis on drought years
  - What level of improvement does inclusion of new remote sensing based terms yield?
  - How does the improvement vary by basin, characteristics (veg. cover, etc.)?
  - How does the improvement vary by degree of drought?

- If hypothesis that remote sensing data provides additional information proves true, Stage 2 would involve exploration of a real-time data assimilation system (“next-generation” forecast method) to better extract such information in a more explicit way [should be more robust to climate change issues that may cause regressions to fail]