Proposal for a Collaborative Project Involving
The Laboratory of Tree-Ring Research (LTRR) & The Salt River Project (SRP)

THE CURRENT DROUGHT IN CONTEXT: A TREE-RING BASED EVALUATION OF WATER SUPPLY VARIABILITY FOR THE SALT-VERDE RIVER BASIN (LTRR-SRP II)

(Duration: 2 years / August 2005-August 2007)

Katherine K. Hirschboeck & David M. Meko
Laboratory of Tree-Ring Research, The University of Arizona

PROJECT SUMMARY

This project will build on the work and results of our previous project with SRP (LTRR-SRP I). The purpose of this follow-up project is to update the tree-ring reconstructions of annual streamflow of the Salt-Verde River basin to cover the period of the most recent drought (through 2004) and the subsequent wet winter of 2004-05, which seemingly ended the drought. The project will also examine the degree to which variations in seasonal precipitation and snow cover can be identified in the tree-ring record in order to provide longterm hydrologic information that is directly applicable to water-user decision making. The results of LTRR-SRP II **will allow SRP to place the most recent droughts of the instrumental period (post -1960s) into a long term, historical context linked to climatic variability.** The new chronologies developed in this study will include the complete ring for growth year 2004, as well as growth year 2005 (in some collections). A companion snowpack study will allow the longterm tree-ring record to be evaluated in terms of modern snow monitoring techniques.

RESEARCH OBJECTIVES

I. To recollect tree ring cores from selected sites in the Salt-Verde watershed in order to update the tree-ring chronologies in the basin through summer 2005.

II. To measure earlywood and latewood widths from the new chronologies in order to analyze the influence of the winter vs. summer component of precipitation on tree growth in the Salt-Verde Basin and to extract seasonal information on drought history and streamflow.

III. To re-calibrate, update, and analyze the Salt-Verde Basin tree-ring reconstructions of streamflow using the new collections, chronologies, and seasonally separated ring width information in order to place the most recent drought and high flow extreme years in the context of the entire record, including present and past climatic variability.

IV. To define the relationship between tree-ring data and winter precipitation (specifically snow depth, snow extent, and snow water equivalent) through both ground-based and remotely sensed observations and use this information to develop a tree-ring-based historical snowpack assessment.

V. To integrate the results of objectives (I) through (IV) into a report that links the longterm tree-ring reconstruction of the Salt-Verde streamflow with recent observations of gaged streamflow, seasonal precipitation, snow cover and climate variability.

WORK PHASES

(1) Collection and recollection of tree ring cores from selected sites in the Salt-Verde watershed in order to develop approximately **15 new tree-ring chronologies** in the Salt and Verde watersheds and to **update the** chronologies **through 2004** and, where possible, **summer 2005.**

(2) Processing of the new collections, including measurement of **earlywood and latewood widths** from the new chronologies to **analyze the influence of the winter vs. summer component of precipitation** on tree growth in the Salt-Verde Basin and to extract seasonal information on drought history and streamflow.

(3) **Re-calibration, updating and analysis** of the Salt-Verde Basin tree-ring reconstructions of streamflow using the new collections, chronologies, and seasonally separated ring width information in order to **place the most recent drought and high flow extreme years in the context of the entire record, including links to present and past climatic variability** (atmospheric circulation patterns, indices, etc.)

(4) Analysis of the relationship between tree-ring data and winter precipitation (specifically **snow depth, snow extent, and snow water equivalent**) through both ground-based and **remotely sensed** observations in order to use this information to develop a **tree-ring-based historical snowpack assessment**.

(5) **Integration of the results** of phases (1) through (4) into a final report that links the longterm tree-ring reconstruction of the Salt-Verde streamflow with recent observations of gaged streamflow, seasonal precipitation, snow cover, and climate variability.

TASKS

a) Field collection and processing of newly collected samples

Trees will be re-sampled from previously visited sites to extend existing chronologies to the present and new sites will be identified and cored as appropriate. Cores will be processed, dated and measured, including **measurement of total ring width, earlywood width and latewood width.**

b) Development of new total ring-width chronologies

All newly collected core measurements will be combined with existing data to develop new total ring-width chronologies for sites in the Salt-Verde Basin. The new collections will include the **complete ring for growth year 2004 and growth year 2005 for some collections**.

c) Development of separate earlywood and latewood chronologies

Separate **earlywood and latewood chronologies** will also be developed based on the techniques described in Meko and Baisin (2001) in order to extract ***seasonal*** **information** on drought history and streamflow from the tree-ring record (see **Figure 1**).

d) Reconstruction of annual and seasonal streamflow, precipitation, and drought indices using the new chronologies

The new tree-ring collections will be used to **update the annual streamflow reconstructions** produced in LTRR-SRP I for the Salt +Tonto, the Verde, and the Salt+Tonto+Verde basins, using the same gages. In addition, reconstructions of **seasonal streamflow, precipitation,** and **drought indices** will also be produced for the Salt-Verde Basin. It is assumed that **earlywood** width (EW) will allow more accurate reconstruction of the **cool-season** component and **latewood** width (LW) will allow separate estimation of the **summer monsoon** contribution.

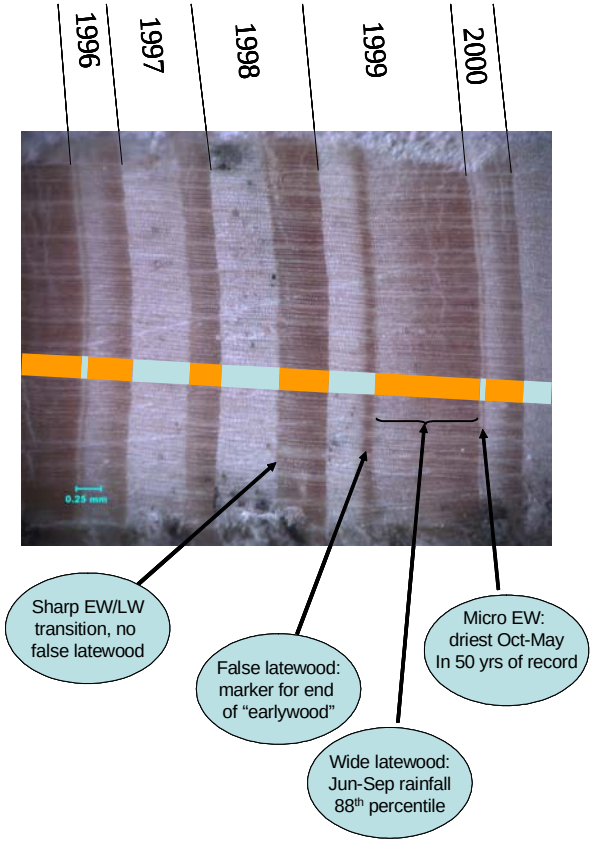


Figure 1. This core illustrates diagnostic features of earlywood and latewood of *Pseudotsuga menziesii* in southeastern Arizona. The time sequence 1996-2000 is significant climatically for having the 5th wettest summer (1999) and the driest (2000) and 4th driest (1996) cool seasons in 50 years of record at Santa Rita Exp Range. The more problematic earlywood/latewood boundary (none shown) is no false latewood but just a gradual transition in density or color.

e) Analysis of reconstructions and assessment of the current drought in context

The newly reconstructed annual and seasonal streamflow, precipitation, and drought index time series will be compared with the instrumental record of the Salt-Verde Basin. Various statistical analyses (as in LTRR-SRP I) will be performed to **evaluate probabilities associated with the current drought in the context of the variability of the past several hundred years.**

f) Ongoing **analysis of the climatic variability** associated with recent and long-term reconstructed streamflow variability.

Building on the initial results of LTRR-SRP-I (e.g., unique circulation anomaly patterns associated with LL, HH, LH and HL years; possible linkage to ENSO, PDO, AMO and other climatic indices) the **climate indices and circulation patterns** that are linked to recent and past streamflow variability in the Salt-Verde basin will be specified and analyzed using the techniques of *synoptic dendroclimatology* (Hirschboeck et al., 1996). The seasonal reconstructions will provide a finer time resolution for this analysis.

g) Development of historical snowpack / snow water equivalent assessment by linking remote sensing and tree rings

Because the winter snowpack and its snow water equivalent (SWE) are vital components of overall streamflow in the Salt-Verde Basin, a companion "historical snowpack/SWE study" will be integrated into LTRR-SRP II. This work, to be completed as part of a Ph.D. dissertation by Ela Czyzowska, will integrate the spatial breadth of remote sensing imagery and the temporal depth of annual (and seasonal) tree-ring information through the variables of snow cover extent and snow water equivalent. As part of a NASA-funded fellowship, Ela will develop the algorithms needed to derive fractional snow cover estimates for an area of the upper San Juan River Basin. Once developed, she will apply her model to the Salt-Verde Basin (as a proof-of-concept test) and will explore the relationship between her satellite-derived snow estimates and tree-ring variability. Her objective is to develop a long-term snow cover/SWE reconstruction for

the basin that is linked to current satellite-based methods of monitoring snow cover. The tree-ring recollection effort of LTRR-SRP II will provide sufficient time overlap of both satellite imagery and tree-ring data to accomplish this task. (see **Figure 2** and **Appendix A**).

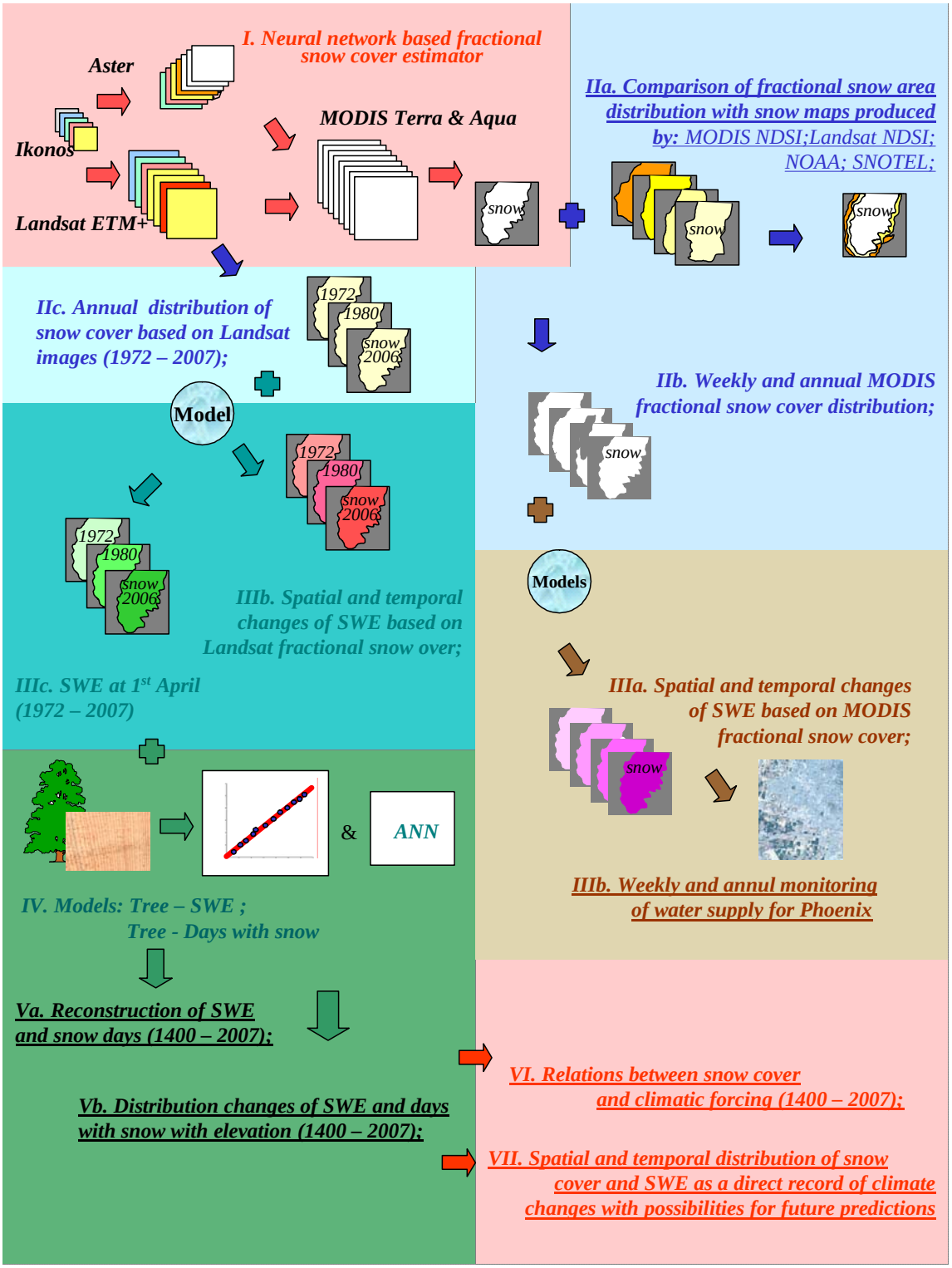


Figure 2. Overview of Research Plan for Companion Snowpack Study

h) Preparation of final report

A final report will be completed that summarizes all phases of the study. It will be made available on the project website and include the deliverables noted below and additional relevant links containing background information on the study.

PROPOSED DELIVERABLES

- Periodic progress reports submitted quarterly (Oct '05; Jan, Apr, Jul, Oct '06; Jan, Apr, '07)
- Final report submitted in September '07 with an accompanying project webpage addition
- New and updated reconstructions for the Salt+Tonto, Verde, and Salt+Verde+Tonto basins (annual and seasonal streamflow, precipitation and drought indices)
- Statistical assessment of current drought based on the updated reconstructions
- Evaluation of the longterm streamflow reconstruction in terms of linkages to recent and past climatic variability (circulation anomalies, indices, etc.)
- Snow cover/SWE study report

SCHEDULE

- Field collections of tree-ring data will be in Year 1 and will involve the following:
  - a total of approximately 20 days of collection by 4-person crew
  - approximately 4 five-day collections trips scheduled as weather and snow conditions permit
  - target of 15 sites distributed in or near Salt and Verde basins
  - sites chosen based on past knowledge of old, drought-sensitive chronologies plus considerations of runoff distribution and synoptic climatology;
  - field collections to include roughly 30 trees per site, with subset of young (<200 yr) trees included to facilitate development of latewood width chronologies
- Sample preparation, cross-dating and measurement to proceed immediately after collections, and to be concluded by month 3 of the second year (July 2006).
- Chronology development to be completed by month 6 of the second year (Oct 2006)
- Climatic and hydrologic reconstructions to be done in the last 6 months of the project (Nov '06 - Apr '07)
- Climatic variability analyses will be ongoing throughout the project period.
- Snowpack/satellite data study (PhD student) to proceed beginning with the start of the project and run thoughout the project period. Additional funding from NASA has been obtained sought for supplemental funding of this dissertation.
- Preliminary assessment by end of Year 1 (April 2006) on relative severity of growth suppression in the most current drought (all chronologies will not yet be available by end of Year 1).

PERSONNEL & RESPONSIBILITIES

Hirschboeck: project management; SRP coordination; supervision of two graduate students (snow project and climate analysis); supervision of undergraduate assistant; climatic analysis; reports.

Meko: supervision of technician; supervision of all field and sample prep; chronology development; reconstructions; data analysis; reports.

Technician: crossdating and measurement of tree-ring data; assistance in chronology quality control and development; assistance in field work

Grad students: PhD project on snowpack, tree rings, and remote sensing; separate climate study on drivers of streamflow variability and extremes (high and low flows)

Undergrad: assistance in data collection, reports, field work

Other: part time assistance for 20 days by 2 students in field

PROPOSED TIMELINE FOR YEARS 1 & 2

Progress reports to be submitted by the end of Oct '05; Jan, Apr, Jul, Oct '06; Jan, Apr, '07

WORK PHASES	Month																							
	SRP Budget Year 1									SRP Budget Year 2														
	2005					2006												2007						
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1. Field collections										Additional field work as needed															
2. Processing & new chronologies																									
3.Re-calibration / update of reconstructions w/ climate analyses		Ongoing climatic analysis, building on LTRR-SRP I ➔																							
4. Snow study																									
5. Integration & final report																									

ESTIMATE BUDGET WITH JUSTIFICATION

(see APPENDIX B)

REFERENCES

Hirschboeck, K.K., Ni, Fenbiao, Wood, M.L., Woodhouse, C.A. (1996) Synoptic dendroclimatology: overview and prospectus, in Dean, J.S., Meko, D.M. and Swetnam, T.W., eds., *Tree Rings, Environment, and Humanity*: Radiocarbon, pp. 205-223.

Meko, D.M. and Baisan, C.H. (2001) Pilot study of latewood-width of conifers as an indicator of variability of summer rainfall in the North American Monsoon region: *International Journal of Climatology*, 21:697-708.

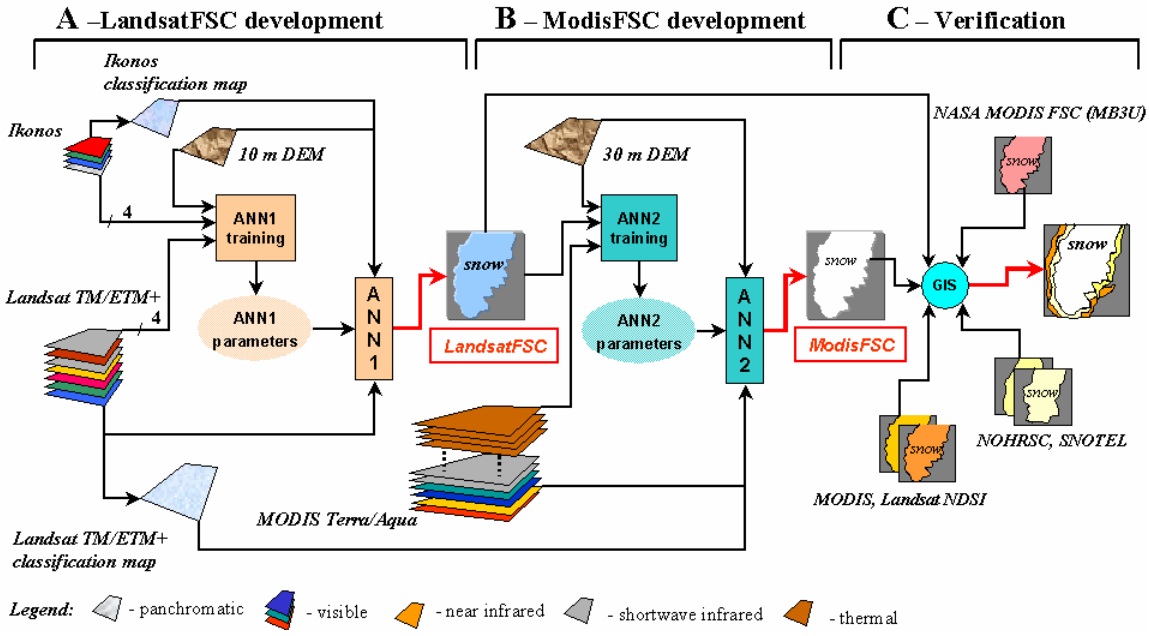
APPENDIX A

NASA Earth System Science (ESS) Graduate Student Fellowship Award (2005-2007)

FRACTIONAL SNOW COVER ESTIMATION IN COMPLEX ALPINE-FORESTED ENVIRONMENTS USING LANDSAT AND MODIS

Ezbieta Czyzowska
Laboratory of Tree-Ring Research & Office of Arid Lands Studies, University of Arizona

Abstract: There is an undisputed need to increase accuracy of fractional snow cover (FSC) estimation in regions of complex terrain, especially in areas dependent on winter snow accumulation for a substantial portion of their water supply, as in Western United States. Observed snow cover extent (SCE) in alpine/forested environments exhibits high sensitivity to variations in climate and water cycle changes. The aim of this research is to develop FSC using a fusion methodology between remotely sensed data at the highest available temporal resolution (daily images; MODIS) and the highest available spatial resolutions (30, 4 and 1 m; Landsat, Ikonos). It is hypothesized that an Artificial Neural Network (ANN) will capture the multi-scaled information structure of the data by means of the ANN training process. Landsat and MODIS fractional snow cover for alpine and/or forested terrain will be derived and the capability of both products to estimate SCE will be validated in a separate watershed.



Information flow during the development of Landsat Fractional Snow Cover (FSC) and Modis FSC with Artificial Neural Networks

LandsatFSC and ModisFSC products derived from this research will be applied on a watershed scale to support water supply management decisions in the Salt –Verde Watershed ofArizona. SWE estimated by the Modified Depletion Curve Method (MDC) and ModisFSC and LandsatFSC will be compared with annual and seasonal streamflow in the Salt-Verde derived principally from snow cover melt. The results of this research will produce estimates of LandsatFSC and ModisFSC that can be applied toward forecasts of the level of water availability at the beginning of an operational year for the Salt-Verde Basin. Finally, the derived LandsatFSC product will offer the opportunity to define the interannual variability of snow cover over a period of 30+ years, providing a basis for merging remotely sensed data with multi-decadal climate observations and proxy records such as tree rings.