UNIVERSITY OF CALIFORNIA, DAVIS

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Ahmad Hakim-Elahi, Ph.D., J.D., Director of Sponsored Programs
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One Shields Avenue
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January 6, 2005

California Department of Water Resources
Office of Water Use Efficiency
Attn: Ms. Debra Gonzalez
1416 Ninth Street, Room 338
Sacramento, CA 95814

Dear Ms. Gonzalez:

Letter in Support of Project Entitled
"California Irrigation Management Information System Phase II"
Principal Investigator- Dr. Richard L. Snyder, UCD

It is our pleasure to forward institutional support and approval of the research project by UCD's Dr. Snyder on the referenced research project to the CA Department of Water Resources under the FINAL 2004 Water Use Efficiency Proposal Solicitation.

Please note that UCD takes exception to some of the provisions and language in the Solicitation. Specifically we call your attention to the following:

Section A-9/ B-9: Paragraph B Reports (Request replacing with GIA 101)
Section A-11/ B-11: Intellectual Property Rights (Request replacing with GIA 101)

Please note that agreements with the above considerations have previously been negotiated with CADWR on behalf of the University of California and agreeable language has been included in current agreements with UC Davis.

Should the Department make an award to the University, we would anticipate negotiating terms that comply with University and federal guidelines as they pertain to the higher learning institutions and retention of intellectual property rights.

Please contact the principal investigator for scientific information. Administrative questions may be directed to David Ricci at 530-752-9753 or via email at fdricci@ucdavis.edu.

Sincerely,

Ahmad Hakim-Elahi, Ph.D., J.D.
Director of Sponsored Programs

cc: Dr. Snyder

UNIVERSITY OF CALIFORNIA
COOPERATIVE EXTENSION

DAVIS, CALIFORNIA
Dept.: Land, Air and Water Resources
Office: 243 Hoagland Hall
Phone: (530) 752-4628
FAX: (530) 752-1793
Email: rlsnyder@ucdavis.edu

REPLY TO:
University of California
One Shields Avenue
Land, Air and Water Resources
Davis, CA 95616-8627
January 9, 2005

Debra Gonzalez
California Department of Water Resources
Office of Water Use Efficiency
P.O. Box 942836,
Sacramento, CA 94236-0001

Dear Ms. Gonzales:

Please find enclosed one original, eight photocopies, and an electronic version of the proposal entitled "**California Irrigation Management Information System *Phase II***".

If you have any questions, please contact me at (530) 752-4628.

Sincerely,

Richard L. Snyder
Biometeorology Specialist

2004 Water Use Efficiency Grant Proposal

For the project entitled:

California Irrigation Management Information System Phase II

Section B: Agricultural and Urban Water Use Efficiency Research Projects

Submitted by:

Principle Investigator: Richard L. Snyder
University of California
One Shields Avenue
Land, Air and Water Resources
Davis, CA 95616-8627

Co-Investigators Susan L. Ustin, UC Davis
Kyaw Tha Paw U, UC Davis
Shu Hua Chen, UC Davis
Dave R. Smart, UC Davis
Judith Z. Drexler, USGS
Neil V. O'Connell, UCCE
Harry L. Carlson, UCCE

APPENDIX A: Project Information Form

Applying for:	☒ Urban ☒ Agricultural
1. (Section A) **Urban or Agricultural Water Use Efficiency Implementation Project**	☐ (a) implementation of Urban Best Management Practice, #_____ ☐ (b) implementation of Agricultural Efficient Water Management Practice, #_____ ☐ (c) implementation of other projects to meet California Bay-Delta Program objectives, Targeted Benefit # or Quantifiable Objective #, if applicable _____ ☐ (d) Specify other: _____
2. (Section B) **Urban or Agricultural Research and Development; Feasibility Studies, Pilot, or Demonstration Projects; Training, Education or Public Information; Technical Assistance**	☒ (e) research and development, feasibility studies, pilot, or demonstration projects ☐ (f) training, education or public information programs with statewide application ☐ (g) technical assistance ☐ (h) other
3. Principal applicant (Organization or affiliation):	Richard L. Snyder, University of California, Davis Department of Land, Air and Water Resources
4. Project Title:	**California Irrigation Management Information System Phase II**
5. Person authorized to sign and submit proposal and contract:	Name, title: Ahmad Hakim-Elahi, Ph.D., J.D. Mailing address: Director of Sponsored Programs Office of the Vice Chancellor for Research Sponsored Programs, 118 Everson Hall University of California One Shields Avenue Davis, California 95616-8671 Telephone Fax. E-mail

6. Contact person (if different)

Name, title	
Mailing address	David Ricci Contracts and Grants Analyst Office of the Vice Chancellor for Research Sponsored Programs, 118 Everson Hall University of California One Shields Avenue Davis, California 95616-8671
Telephone	(530) 752-9753, FAX (530) 754-9233
Fax.	
E-mail	fdricci@ucdavis.edu

7. Grant funds requested (dollar amount): _____
(from Table C-1, column VI)

8. Applicant funds pledged (dollar amount): _____

9.Total project costs (dollar amount): _____
(from Table C-1, column IV, row n)

10. Percent of State share requested (%) _____100%_____
(from Table C-1)

11. Percent of local share as match (%) _____
(from Table C-1)

12. Is your project locally cost effective?
Locally cost effective means that the benefits to an entity (in dollar terms) of implementing a program exceed the costs of that program within the boundaries of that entity.

☐ (a) yes

(If yes, provide information that the project in addition to Bay-Delta benefit meets one of the following conditions: broad transferable benefits, overcome implementation barriers, or accelerate implementation.)

☒ (b) no

11. Is your project required by regulation, law or contract? If no, your project is eligible.

☐ (a) yes

If yes, your project may be eligible only if there will be accelerated implementation to fulfill a future requirement and is not currently required.

☒ (b) no

Provide a description of the regulation, law or contract and an explanation of why the project is not currently required.

_____
_____
_____

12. Duration of project (month/year to month/year): Jan. 2006 –December 2007
13. State Assembly District where the project is to be conducted: ??? District

14. State Senate District where the project is to be conducted: ??? District

15. Congressional district(s) where the project is to be conducted: ??? District

16. County where the project is to be conducted: _____Statewide___

17. Location of project (longitude and latitude)

18. How many service connections in your service area (urban)?

19. How many acre-feet of water per year does your agency serve?

20. Type of applicant (select one):

☐ (a) City
☐ (b) County
☐ (c) City and County
☐ (d) Joint Powers Authority
☐ (e) Public Water District
☐ (f) Tribe
☐ (g) Non Profit Organization
☒ (h) University, College
☐ (i) State Agency
☐ (j) Federal Agency
☐ (k) Other

(i) Investor-Owned Utility

(ii) Incorporated Mutual Water Co.

(iii) Specify _____

21. Is applicant a disadvantaged community? If 'yes' include annual median household income. (Provide supporting documentation.)

☐ (a) yes, _____ median household income
☒ (b) no

APPENDIX B: Signature Page

By signing below, the official declares the following:

The truthfulness of all representations in the proposal;

The individual signing the form has the legal authority to submit the proposal on behalf of the applicant;

There is no pending litigation that may impact the financial condition of the applicant or its ability to complete the proposed project;

The individual signing the form read and understood the conflict of interest and confidentiality section and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant;

The applicant will comply with all terms and conditions identified in this PSP if selected for funding; and

The applicant has legal authority to enter into a contract with the State.

	Ahmad Hakim-Elahi, Ph.D., J.D FOR Director of Sponsored Programs	1/6/05
Signature	Name and title	Date

A. PROJECT SUMMARY

In this project, our goal is to couple the Advanced Canopy-Atmosphere-Soil Algorithm (ACASA) turbulence flux model with the mesoscale Weather Research and Forecast (WRF) model (WRF-ACASA) to provide forecasts of actual ET_c anywhere within the State of California. Remote sensing will be used to estimate ET_c directly and to improve initial and boundary conditions needed for the WRF-ACASA models. A GIS database will provide an easy format to access the information. It is envisioned that a California map will be provided on the Internet and users will click on a pixel to collect near real-time and short-term forecasts of ET_o. For surfaces where the surface conditions can be determined by remote sensing, short-term forecasts of ET_c will also be provided. In instances where the surface conditions are unknown from remote sensing, growers or landscape professionals can input vegetation characteristics (e.g., crop type, ground cover and roughness) for a surface within a pixel to forecast ET_c using the stand-alone ACASA model which employs meteorological parameters from WRF-ACASA forecasts. For example, the ET_c for alfalfa varies dramatically before and after cutting, so input of the crop height will be needed for ACASA to know that the roughness characteristics have changed. When completed, the CIMIS II system will again put California at the forefront of any State or Country for water management, and it will offer an improved cost-effective timely method to provide the information that growers and landscape professionals need to manage water supplies.

To our knowledge, a similar system to the WRF-ACASA model does not exist anywhere in the world. This project will eliminate the need for crop coefficients, which a major limitation to grower adoption. It will provide a forecast as well as near-real time crop evapotranspiration (ET_c) data rather than only near-real time reference evapotranspiration (ET_o) data as is currently provided by CIMIS. This will provide the exact information needed to do irrigation scheduling to growers and landscape professionals using high frequency irrigation methods. It will provide site specific information for any location in the state, which will greatly reduce the need for large numbers of CIMIS stations and the problems associated with non-ideal station locations. It is anticipated that the CIMIS II will reduce CIMIS operational costs and savings to the State will pay for this project within a few years. The information simplification will enhance grower and landscape professional use of ET information, which will greatly benefit California.

At the same time as the WRF-ACASA model is developed, field measurements will be conducted and used to validate the WRF-ACASA model and to develop and improve crop coefficients for use with the current CIMIS network. This will improve ET_c estimation during a transition from use of CIMIS to CIMIS II.

B. STATEMENT OF WORK

Section One: Relevance and Importance

The development of CIMIS was a major cooperative accomplishment between the California Department of Water Resources and the University of California, and many aspects of the system have been copied and implemented by other States and countries. The original CIMIS project began in July 1982 and completed in June 1985. At that time, there were few automated weather station networks, virtually no personal computers, and no networks dedicated to providing evapotranspiration (*ET*) information to growers for use in irrigation scheduling. Nonetheless, the original CIMIS project accomplished the following tasks:

1. Established a weather network of 45 automated stations
2. Established a central computer to query the stations once per day, to provide quality control of the weather data and to calculate reference evapotranspiration (ET_o) using hourly weather data.
3. Developed the ET_o data and crop coefficients and field tested to verify accuracy
4. Developed techniques to evaluate irrigation systems which contributed to establishment of Mobile System Evaluation Laboratories.
5. Evaluated grower adoption and methods to encourage technology transfer of the CIMIS information.

Since CIMIS was completed, its cost effectiveness was evaluated by Parker et al. (2000) who reported that maintenance and operation costs about $850,000 per year but the benefits to growers, from increased profits alone, due to better irrigation management, amounted to about $64,700,000 per year. This estimate does not include additional benefits resulting from use of weather data for pest management, wildfire management, frost protection, etc. Clearly, the development of CIMIS demonstrated that California is at the forefront of water management.

Although CIMIS is a tremendous resource, the actual computation of crop evapotranspiration (ET_c) still requires the application of crop coefficients, which makes it somewhat difficult for all but the most sophisticated growers to apply. There is a need to go the next step and directly provide accurate ET_c to growers in a timely fashion without the need for complicated computer programs. For several years following the development of CIMIS this was not possible. However, with the development of the internet, improved remote sensing, mesoscale computer models, and high-powered micro-scale turbulence and flux models, it now is possible to accurately estimate ET_c remotely and easily disseminate that information to potential users. In fact, with today's models we can provide weather and ET_o forecasts for the entire state, we can directly estimate ET_c, and we can interpolate between weather stations thus potentially reducing the number of stations while improving estimates of ET_c at locations without CIMIS weather stations.

In the CIMIS II project, our goal is to couple the Advanced Canopy-Atmosphere-Soil Algorithm (ACASA) turbulence flux model with the mesoscale Weather Research and Forecast (WRF) model (WRF-ACASA) to provide short-term forecasts of actual ET_c anywhere within the State. Remote sensing will be used to improve initial and boundary conditions needed for the WRF-ACASA models and to validate model forecasts. A GIS database will provide an easy format to access the information. It is envisioned that a California map will be provided on the Internet and users will click on a pixel to collect near real-time and short-term forecasts of ET_o. Because surface roughness and stability conditions are needed to determine ET_c, in addition to pre-forecasted ET_c, growers can input specific crop characteristics (e.g., crop type, ground cover, and roughness) different from model default within that pixel to reforecast ET_c using the stand-alone ACASA model which takes meteorological parameters from WRF-ACASA forecasts. For example, the ET_c for alfalfa varies dramatically before and after cutting, so input of the crop height will be needed for ACASA to know that the roughness characteristics have changed. When completed, the new CIMIS II system will again put California at the forefront of any State or Country for water management, and it will offer an improved cost-effective timely method to provide the information that growers need to manage water supplies.

Goals and Objectives:

1. To estimate ET_o on about a 5 km grid scale using remote sensing data and WRF-ACASA. The spatial integration of weather data and ET_o estimates will reduce the need for large

numbers of new CIMIS stations (to increase statewide coverage) and will provide ET_c estimates in many areas (e.g. in urban areas) where no sites exist that meet CIMIS siting criteria. This will greatly reduce the cost of operating the CIMIS network and the savings could easily compensate for expenses incurred in this project within a few years. The 5 km grid of hourly ET_c information for California will greatly enhance irrigation management and long-term water resources planning by State agencies.

2. To support water resource planning by using the WRF-ACASA and remote sensing data to develop spatial estimates of crop evapotranspiration (ET_c) within regions.
3. To develop field-specific estimates of ET_c at any location within California for the crops studied using WRF-ACASA and user input surface information.
4. To develop the capability to disseminate near-real time and short-term forecast data to the public via the use of Internet maps and minimal user input information.
5. To conduct extensive monitoring of crop evapotranspiration that verify ET_o and ET_c estimates from the CIMIS II combination model for a range surfaces, including irrigated pasture, alfalfa, cotton, rice, potatoes, citrus, grapevines, almonds and natural ecosystems (e.g., wetlands and forests).

Section Two: Technical/Scientific Merit, Feasibility

Weather Research and Forecast (WRF) Mesoscale Forecast Model

The WRF model is a joint development effort (Klemp et al. 2000, Michalakes et al. 2001, Chen and Dudhia 2000) among several organizations and institutes including, NCAR, NCEP/NOAA, NASA, FSL/NOAA, and others. On a national level, in the near future, WRF will replace MM5, which is the current community mesoscale model, the Fifth-Generation NCAR / Penn State Mesoscale Model version 3 (Grell et al 1994). The WRF model was chosen for the CIMIS II project because of following features:

a) The WRF is a fully compressible, non-hydrostatic model, and the governing equations are written in flux form to conserve mass, dry entropy, and scalars.
b) High-order accurate numerical schemes are used.
c) The Arakawa C grid is used and the nesting capability has been implemented, so the model is capable of doing high resolution simulations.
d) A 3DVAR has been developed to be incorporated into the WRF model. Through this 3DVAR system, conventional and unconventional data (e.g., satellite data) can be assimilated to improve model initial conditions.
e) A reasonably complete set of physics components has been implemented (Chen and Dudhia 2000). The model is well-modularized and it is easy to implement new micro-scale physics schemes such as ACASA.

The state-of-art WRF model was designed to incorporate advanced physics (Chen and Sun 2002; Hong et al. 2004) and data assimilation systems in model predictions. Therefore, the WRF model is particularly suitable for the CIMIS II proposed study.

We have previous experience in using the WRF model to directly forecast hourly ET_o, but without the use of ACASA or remote sensing data. In the prior study, the nesting capability was not implemented and only one domain was used. After calibration, the forecasted ET_o error was about 15%, and the major error contributors were due to the timing of wind speed and humidity (i.e., dew points). Another contributing error might have been due to the coarse spatial resolution, which can be improved using the WRF nesting technique proposed here. The errors

in predicted wind speeds and humidity most likely came from inaccurate initial conditions and overly simplified physics schemes such as the land-surface model. Therefore, using a sophisticated land-surface model (e.g., ACASA) will likely improve the characterization of surface processes and the WRF model forecast. In addition, the direct assimilation of observations from remote sensing will improve initial conditions and improve WRF model forecasts.

UC Davis Advanced Canopy-Atmosphere-Soil Algorithm (ACASA) Model

The University of California's ACASA model is based on the work of Meyers (1985), Meyers and Paw U (1986), Meyers and Paw U (1987), and Pyles (2000). Note that the ACASA model is not to be confused with NASA or Carnegie Institution's CASA models (i.e., models developed by Potter et al. 2003 or by Field et al., 1995). ACASA has shown promise for estimating realistic fluxes and surface-layer meteorological conditions, both as a stand-alone soil-plant-atmosphere model and when coupled to a regional-scale atmospheric model such as MM5 (Pyles et al. 2000, 2003). In the current investigation, ACASA includes 20 atmospheric layers (10 within the canopy, 10 extending to at least twice the canopy height) and 15 soil layers. ACASA uses a near-exact quartic energy balance formulation (Paw U and Gao 1988) that enables ACASA to accurately calculate surface temperatures even in situations where leaf, stem, or soil surface temperatures differ significantly from ambient air temperatures. A 4th order, best-fit polynomial is used for the saturation vapor pressure, with a different set of coefficients for leaf, stem, and soil/snow temperature intervals of 0.1 ^{o}C between -100 ^{o}C and +100 ^{o}C. These different sets of coefficients extend the work of Paw U and Gao (1988) enabling ACASA surface temperature calculations to be relevant between the ranges of temperatures found in the vast majority of cases on Earth, instead of the +5° to +45 ^{o}C range appropriate to the original formulation (Paw U and Gao 1988). A diabatic, third-order closure method describes turbulent transfer within and above the canopy (Meyers 1985).

To estimate ET, one needs to know how vegetation physiologically responds to changing microenvironmental conditions (e.g. radiative, temperature, humidity, wind speed, CO2 concentrations). ACASA represents these plant physiological responses using a variety of computational techniques (Paw U 1997). In particular, ACASA treats plant physiological response to environmental conditions using a combination of the Ball-Berry stomatal conductance (Leuning 1990; Collatz et al., 1991) and the Farquhar and von Caemmerer (1982) photosynthesis equations. These formulations were combined to yield estimates of unstressed stomatal resistance within each canopy layer in Su et al. (1996). Total stomatal resistance estimates reflect the combined influences of above- and below-ground conditions. Besides allowing for plant physiology and canopy microenvironment to act as an interconnected system, use of this model is advantageous because the parameters it requires are generally constrained (Collatz et al., 1991; Leuning, 1990; Harley and Tenhunen, 1991; De Pury, 1995). Only under conditions of moderate to severe soil moisture deficits (Sala and Tenhunen 1994; Baldocchi 1997) or cases involving old trees with decreased hydraulic conductivity (Falge et al., 1996) do these parameters deviate significantly from cardinal values. Under stressed conditions, the slopes of the Ball-Berry stomatal conductance regression line are altered to reflect greater degrees of stomatal closure (Baldocchi, 1999).

Meteorological forcing quantities needed to drive ACASA include pressure, air temperature, mean wind speed, specific humidity, downwelling short-wave (solar) and long-wave (thermal infrared) radiation, the solar zenith angle, precipitation rate, the magnitude of the horizontal pressure gradient, and the height of these forcing inputs. Each run of ACASA represents

turbulent statistics and mean quantities averaged over a specified time step (usually every 15 minutes to 1 hour) at one horizontal gridpoint location.

Additional features include a soil and/or snow thermal and hydrological model (Smirnova et al., 2000). A more general description of ACASA can be found in Pyles et al. (2000). ACASA also includes detailed visible, near-infrared, and thermal-infrared radiative transfer (Paw U, 1992), canopy sensible, latent, CO2, and biomass heat storage calculations, canopy interception of precipitation.

WRF-ACASA Model configuration

ACASA is currently being coupled with WRF (WRF-ACASA) to provide surface and near surface fluxes and tendencies in temperature, humidity, momentum (wind), and CO_2 concentration needed by WRF. It is these forcings, provided by ACASA, that enable WRF to properly estimate changes to atmospheric motions as they are coupled with the earth's surface including vegetation and urban areas.

To have high resolution forecasts in regions of interest (i.e., Central Valley), three domains with two-way interaction will be configured. The resolutions for domains 1, 2, and 3 are 15 km, 5 km, and 1 km, respectively, at a vertical resolution of 30+ layers in the lowest 2 km of the atmosphere. This will allow for WRF-ACASA to simulate complex flows within the boundary layer as they develop and change. Such simulations will be more adaptable for small valleys and other areas that are used for agricultural or restorative purposes., Moreover, the WRF-ACASA model can forecast weather down to a relatively small (i.e., 1 km) scale to feed information to the smaller scale stand-alone ACASA model. The NCAR-NCEP reanalysis will be used to create initial conditions (or the first guess of 3DVAR) and boundary conditions for WRF-ACASA .

Forecasts will be made up to 72 hours in advance from each run, including ET_o and ET_c., and maps will be generated where the user can click on a given geographical point (with zoom-in capabilities). A similar idea is being used at the NWS website (www.nws.noaa.gov) where the user can click on a point anywhere in the U.S., the map will zoom in, and the user can get a point forecast and current conditions for any place, corresponding to the nearby NWS ETA-Model grid point. A prototype webpage from the Sacramento NWS Office is already available at the URL: http://ifps.wrh.noaa.gov/cgi-bin/dwf?siteID=STO.

All model output will be stored to allow users to choose a range of items to view, from 200 mb geopotential height fields to current temperatures within the lowest 50 meters of the surface for all California valleys. An archive will be kept to allow users to look at the recent climate and water/energy flux history for their region or point of interest.

In this study, we propose to develop a similar map interface for California to that of the NWS that is resolvable to points corresponding to1 km, 5 km and 15 km grid spacing. Recent past weather and ET_o conditions and a 72 hour forecast (from the model initiation) would ensue and would be available.

Downscaling

If higher resolution data (smaller than 1 km) are available, downscaling will be done at WRF-ACASA model initiation to redistribute the sub-grid scale features within a grid box. Sub-grid scale vegetation and soil type information from remote sensing, NRCS GIS soils data (e.g., STATSGO), or user inputs, will allow ACASA to better integrate energy and scalar fluxes within a grid box. Alternatively, ACASA can be run nested within the WRF-ACASA model with a higher resolution than 1 km to better predict important surface processes.

One methodology for obtaining the sub-grid scale data is to allow user input. The proposed California map will have the option for users to manually input the crop or type of vegetation for a given point of interest. Required input information would include:

1. plant species/variety
2. canopy height and/or ground cover
3. approximate plant spacing.

Using this 'tailored' information, ACASA would be run in a 'top-down' single-point mode with the WRF-ACASA background meteorological forcings (i.e., including soil temperature and moisture profiles in and beneath the root zone). By 'top-down' we mean the WRF-ACASA model will be run at a 1 km grid level (i.e., with the 1 km average vegetation type) to create an 'ambient' atmospheric state. The additional option would use this 'ambient' state and the user-input details of crop or vegetation type as input to a single ACASA run for the user specified location. Since a single ACASA run takes less than 0.1 seconds and demands ~350K RAM, having ACASA run upon request is computationally inexpensive. The user can specify how long the ACASA point simulation would be necessary--for current conditions up to the full extent of the WRF-ACASA forecast regime. From the top-down model, both estimated actual evapotranspiration (ET_a) and reference evapotranspiration (ET_o) would be simulated. The user could then elect to receive more detailed information tailored to their type of crop or landscape that would help them make informed decisions and avoid certain unfavorable risks. Among these would be ACASA-estimated canopy air and leaf vertical mean temperature profiles, PAR profiles, humidity profiles, soil temperature and moisture profiles, carbon dioxide exchanges, turbulent quantities (including TKE, a measure of how 'gusty' the winds are in the field), etc.

This data would enable the user, among other things, to keep track of how much moisture has been leaving the system, and therefore get a better idea on when/what to plant and/or irrigate. For example, by looking at the temperature and humidity variation within the vineyard, viticulturalists can estimate how close together to plant grapes to maximize growth and grape quality while minimizing water use and fungal growth. Using the WRF-ACASA system, such a user could specify grape canopies of varying heights and densities and choose canopies that minimize day-to-day variation of canopy temperature and humidity, watering regimes, etc., before planting the first vine.

Other growers also would be able to 'optimize' planned canopies using the proposed system for additional applications. Such applications using ACASA results include how to arrange a canopy for frost prevention and microclimate adaptation and modification. People interested in air pollution mitigation could develop restorative canopies in urban areas that use the system to determine the best number and arrangement of trees to reduce pollution and regulate temperature. One could, conceivably, play with different types of canopies and determine whether an ecologically restored hillside will be able to survive the dry season and which arrangements of planting would enhance probabilities of survival.

Data assimilation

It has been reported that hurricane simulations are improved by the assimilation of the Special Sensor Microwave/Imager (SSM/I) data (Chen et al. 2004) due to improvements in humidity and low level wind conditions. Because SSM/I data are available only over water, we propose to assimilate reliable alternative data over the land (e.g., surface humidity, temperature, and wind data from National Weather Service (NWS) and CIMIS stations, vertical column temperature and moisture from MODIS satellite products, and wind vectors from wind profilers) to improve initial humidity and wind conditions for the WRF-ACASA.

Model testing

To test the WRF-ACASA model, different configurations will be routinely run for comparison of:

1) ACASA (i.e., WRF-ACASA) vs. non-ACASA (i.e., WRF with other land surface models) runs
2) Data assimilation vs. non-data assimilation runs

Validation

We will use independent observations (i.e., different from initial time) from NWS surface stations, radiosondes (upper air), CIMIS stations, field data (new stations) and satellites (e.g., GOES, MODIS) etc. to validate WRF-ACASA forecasts for moisture, temperature, low level winds, clouds, precipitation, surface heat fluxes, net short wave radiation on the ground and ET_o.

To develop decoders for converting observations (e.g., from wind profilers and satellites) into WRF 3DVAR input format, to implement observational operators into WRF 3DVAR, to perform data assimilation and WRF-ACASA simulations, and to analyze model simulation results, one post doctoral researcher (1.0 FTE all year) and one graduate student researcher (0.5 FTE academic year, 1.0 FTE summer) will be needed.

Remote Sensing/ Model Interactions

Figure 1 provides an overview of how the data products that are used and/or will be produced in this project are integrated. There are four major categories of data products. WRF model input and output parameters are resolved at the coarsest scale, ranging from about 1-15 km^2. The WRF model will be run at multiple resolutions (described above), and we anticipate running it at a coarser scale on the boundary of California, and at finer scales for most of California, where the finer grids result in significant changes to the model predictions.

At the next higher level of scale, data are derived from MODIS and GOES remote sensing imagery, or models developed from such input data. These data are at the scales of 0.25-2.0 km^2 with most data at a scale of 1 km. This includes most of MODIS data products such as temperature and moisture, used to improve WRF initial conditions through a data assimilation technique, as well as data for the finer scale ACASA model outputs.

Landsat Thematic Mapper (TM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data products are available at finer scales of 30-90 m pixels. These data will not be used operationally, but instead provide one method for validation of the land cover characteristics used in WRF and ACASA models, model outputs, and as a way to check the reliability of integrating ET_c estimations for coarser scale statewide products.

At the point or local data scale, users and researchers will run the ACASA model, coupling the model predicted state variables with custom land surface (crop) parameters to determine ET_c estimations for specific surface parameters.

How all these different data products at their relative scales are combined to estimate ET_c for California is shown schematically in Figure 2, which depicts the process steps in the formulation of the ET_c prediction. The notional scale of the individual input and output image layers matches those of Figure 1. The process generally moves left to right across the figure, and tends toward higher resolution from top to bottom.

The first step in producing a statewide spatially distributed map of ET_c shows that data will be retrieved from the MODIS satellite sensors. The atmospheric products from the remote sensing inputs, such as moisture, temperature, and winds, will be assimilated to improve WRF initial conditions.

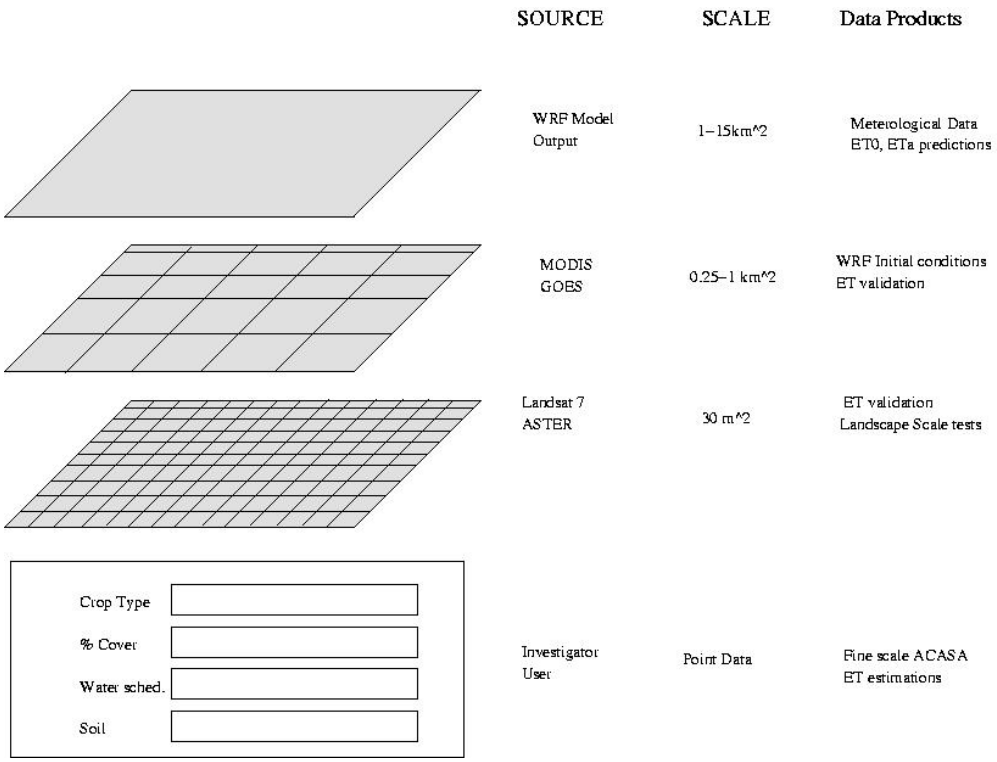

Figure 1: CIMIS II Data Products.

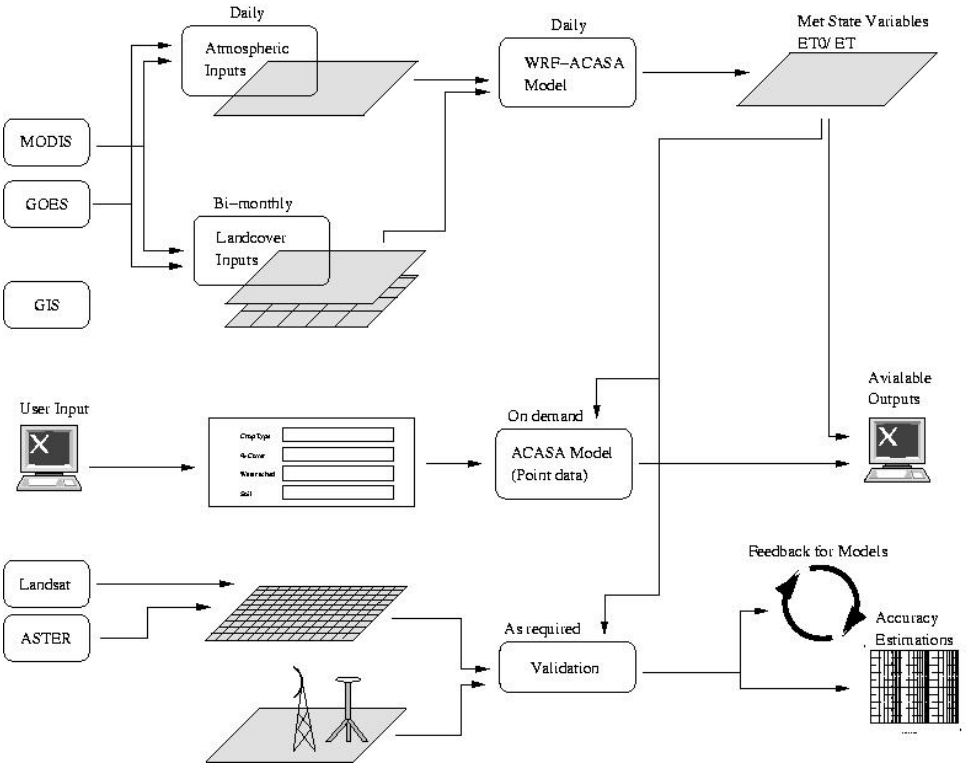

Figure 2: CIMIS II Process

On a bi-monthly schedule, other satellite data products will be used to develop the land surface input parameters for the WRF model. Since Land Surface MODIS data (type and % cover) does not match the model inputs, conversion from MODIS data products to WRF-ACASA model inputs may become more involved, potentially requiring additional GIS layers for completeness. These land surface inputs will be calculated at two scales, one at the scale appropriate for WRF-ACASA, and another at a finer scale. Because the WRF model will be coupled with ACASA model for the boundary interactions, these inputs will otherwise be the same.

Having obtained all model inputs, as mentioned earlier the WRF model will be run on a daily basis to make weather predictions up to 72 hours in advance of current time. These predictions will include boundary layer meteorological estimates, including ET_o and ET_c.

Data users will have the ability to refine ET_c estimations through a web-based interface. For this, users will enter land surface parameters. A one-dimensional formulation of the ACASA model will be run using these surface parameters along with the WRF-ACASA output parameters, to customize ET_c estimations for specific locations. The land surface inputs will be defined with simple features (e.g. crop type, maturity) available from a grower.

This project will also provide validation and calibration of the system with additional measurements. These will include Landsat TM and/or ASTER image data acquisitions for specific times and places in California, as well as point data obtained with field operations. Point data will allow comparison to actual ET measurements, and comparison of the ACASA model to eddy correlation measurements. The finer scale of the Landsat/ASTER data can be used to test the validity of the ACASA model at the integration scales of the daily MODIS derived datasets, and to provide calibration of the land surface parameters for this scale. These experiments will be used both to test the accuracy of the daily model predictions as well as to provide feedback into the models and their inputs.

Remote Sensing Data Sources

This project anticipates using data products from GOES (Geostationary Observational Environmental Satellite), MODIS (Moderate Resolution Imaging Spectrometer), ASTER, Landsat TM, and potentially other remote sensing instruments, e.g., Clouds and the Earth's Radiant Energy System (CERES). GOES data are available every 15 minutes at pixel scales ranging from 1-8 km, depending on the sensor bands (5 image bands; 19 sounder bands). MODIS data is available from both the Terra and Aqua EOS platforms (morning and afternoon, respectively), for four overpasses per day at pixel scales of 250 m to 1 km, depending on the band (36 bands). Many EOS data products of value for this project are derived at 1 km scale and available on a daily basis. The ASTER sensor is also on the Terra satellite, with data products available at 15 m to 60 m pixel sizes, depending on the band (14 bands). The availability of ASTER data is quite variable because it acquires data “on demand” and is not a global mapping instrument. However, data can be requested from NASA for specific sites and dates at no cost if the request is approved. Landsat TM data is available from either Landsat 5 or 7 satellites, with spatial measuring capabilities similar to ASTER, but with more overpasses available (instruments acquire global coverage every 16 days). We will use Landsat data to validate interpretations as part of a subsampling scheme, where it is available, and where the scale is appropriate. Landsat 7 data has reduced availability since 2003, due to a mechanical problem with the instrument; Landsat 5 data is available to fill data gaps.

MODIS data products will be used to improve the initial conditions for the WRF Model. For the atmospheric parameters, these data will be used on a daily basis. The MODIS products include precipitable water, and vertical atmospheric profile datasets (e.g., temperature, humidity). Current investigations have included using the MODIS radiance values as direct inputs to the WRF 3DVAR. For these cases, MODIS radiances will be assimilated in WRF 3DVAR for this project as well to improve WRF-ACASA model initial conditions.

The MODIS data products can be used also to derive land surface parameters that are used to improve the initial conditions for the WRF-ACASA model for these parameters. Required land surface parameters include: albedo, emissivity, heat capacity, surface roughness, soil moisture and thermal inertia. The MODIS data products that can improve predictions of land surface parameters for the WRF-ACASA model include: (1) surface reflectance, (2) land surface temperature and emissivity, (3) LAI and FPAR and (4) vegetation index. Since these parameters change more slowly than the weather input, initial conditions for the WRF-ACASA model based on these parameters can be updated on a weekly time scale or even longer intervals.

These data products can also be used to validate the WRF-ACASA model outputs, either the direct weather parameters or the derived parameters such as evapotranspiration. Because of the temporal scale of GOES data, it can be used as a check on the WRF-ACASA model output at finer temporal resolutions than the six to 12 hour MODIS data products. In addition, MODIS generated evapotranspiration data product (i.e., a simple model formulation of evapotranspiration) will be used to compare to the WRF-ACASA evapotranspiration predictions and field site data.

The ASTER and Landsat data products will be used primarily as a method to investigate the effects of spatial integration on the ET_c estimations. Since the resolutions of both the MODIS and WRF model are coarse with respect to agricultural fields, these satellite data products will be used to look at whether the ACASA estimates of ET_c are accurate averages of the larger scale land surface effects.

The number of acquisitions of Landsat and/or ASTER data will be significantly less than the MODIS data. We require only a small number of acquisitions of these data per year and only for areas of special interest coinciding with the crop distributions already identified in this proposal.

Finally, data products available from various California state agencies will be obtained as well. For example, California's Department of Forestry and Fire Protection produces a statewide land cover map (i.e., a map of 13 land cover classes), which is derived from multi-source data.

MODIS

There are 44 different data products derived from MODIS data, on either the Aqua or Terra EOS platforms, or on both platforms. A few of the data products having special importance for this project are briefly described below.

All MODIS Atmosphere data products are available to the public at no charge. Many of the data archive(s) data sets are available for direct download through web and FTP links. These links offer a convenient interface for near real-time data access and could be used as the source for WRF, ACASA, and validation efforts for this project.

Precipitable Water

The MODIS precipitable water product consists of column water-vapor amounts. During the daytime, a near-infrared algorithm is applied over cloud-free land areas of the globe and above clouds over both land and ocean. An infrared algorithm for deriving atmospheric profiles is also applied both day and night. The data are generated at 5×5 1-km pixel resolution both day and night using the infra-red algorithm when at least nine pixels are cloud free.

Atmospheric Profile

The MODIS atmospheric profile product consists of several parameters including: atmospheric stability, temperature and moisture profiles and atmospheric water vapor. All of these parameters are produced day and night for *Level 2* at 5×5 1-km pixel resolution when at least 9 pixels are cloud free..

Albedo

Global albedo Products are operationally produced every 16 days at 1 km spatial resolution.

Surface Reflectance

This product is an estimate of the surface spectral reflectance for each band as it would have been measured at ground level if there were no atmospheric scattering or absorption.

LAI and FPAR

The MOD 15 Leaf Area Index (LAI) and Fraction of Photosynthetically Active Radiation absorbed by vegetation (FPAR) are 1 km at-launch products provided on a daily and 8-day basis.

Vegetation Index

The MODIS Vegetation-Index (VI) products provide consistent spatial and temporal comparisons of global vegetation conditions. Vegetation- index maps depicting spatial and temporal variations in vegetation activity are derived at 8-day, 16-day, and monthly intervals.

Evapotranspiration

This product consists of surface resistance and evapotranspiration (ET) parameters and has a temporal resolution of eight days at a spatial resolution of 1 km over the land surface only.

GOES

UC Davis has a GOES satellite receiving station and has developed the capability to efficiently process the data for near real-time estimates of various surface parameters including ET_o. We already provide this information to the public via web based Internet tools.

Daily maps of solar insolation from the GOES imager combining the approximately 1 hour interval data as well as methodologies for deriving it are available. Solar insolation calculations are a combination of radiance models coupled with GOES estimated cloud cover amounts.

GOES data is in some ways a coarser but more-timely sensor suite than MODIS data, and GOES can provide similar data products. GOES satellite data include other near infra-red and shortwave-infrared sensors that can be used for water vapor products. Thermal bands allow spatial modeling of land surface temperatures. The GOES sounder data allow for vertical profiling of temperature and water vapor profiles.

Landsat and ASTER

Landsat and ASTER data provide high spatial resolution datasets that are used to validate the coarser MODIS data for specific areas of the state. Landsat has seven bands, six in the reflected solar infared that are acquired at 30m resolution and a thermal band at 90m resolution. ASTER has 14 bands, eight in the reflected solar infrared, two bands at 15 m and six at 30 m resolution and six thermal emissive bands at 90 m resolution. The high spatial resolution of these sensors allows investigation of finer scale landscapes and subfield-level agricultural variability. ASTER is co-located with MODIS on the EOS Terra satellite and Terra is in formation within 0.5 hr. crossing time of Landsat 7. ASTER data is available at no cost when it is archived but it has limited data acquisitions. Landsat data is available at a minimal cost

To analyze the remote sensing data and provide the interface to WRF and ACASA, we will need one post doctoral researcher (1.0 FTE all year), one graduate student researcher (0.5 FTE academic year and 1.0 FTE summer) and one junior specialist (1.0 FTE all year).

Field Monitoring

Field validation of ET_c will be achieved mainly using lysimeters, eddy covariance and surface renewal techniques. The U.C. Davis lysimeters will provide some of the ET_c data and eddy covariance systems including 3-dimensional sonic anemometers, infrared gas analyzers, net radiometers and soil heat flux plates will be used to monitor *ET* (and CO_2 fluxes) at remote locations. The less expensive surface renewal stations, which consist of net radiometers, soil heat flux plates and fine-wire thermocouples will be used to replicate ET_c measurements at additional locations where needed. In general, we will install one eddy covariance and two surface renewal systems for each of the crops or wetlands studied. In addition, data will be collected on canopy cover (% surface cover by type), leaf area index (LAI) and other plant factors as needed. In addition, to the crops and natural systems specifically monitored in this project, we will also investigate the possibility of including other natural ecosystems that are being monitored as part of the U.S. AmeriFlux network and use them as additional validation sites for *ET* and CO_2 fluxes. These data are being collected and monitored by researchers at UC Berkeley, UC Irvine, Stanford University, Oregon State University and San Diego State University and their flux data are available free from the US Department of Energy. We will also determine whether the CIMIS II network data can provide useful information on water availability and use in rangelands and forests for the California Department of Forestry and Fire Protection and other government agencies.

Eddy covariance measurements

Eddy covariance is one method that will be used to validate WRF-ACASA evapotranspiration estimates. A net transport of some specific entity across a horizontal plane implies a correlation between the vertical wind component and that entity. Therefore, if water vapor is released from the surface into the atmosphere, updrafts will generally contain higher vapor content than downdrafts and the positive (upward) vertical velocity will be positively correlated with vapor content. This relationship is calucalated by separating the perturbation and the time-averaged water vapor density (kg m^{-3}) as $\rho_v = \overline{\rho_v} + \rho_v'$ provides an expression for absolute humidity, where the overbar signifies a time average over a specified interval of time and the prime indicates a departure from the mean. Similarly, $w = \overline{w} + w'$, where *w* is the vertical velocity. By definition, $\overline{w'} = 0$ and $\overline{\rho_v'} = 0$ and, if the mean flow is horizontal, then $\overline{w} = 0$. It can be shown that the flux density for water vapor *E* (kg m^{-2}s^{-1}) is equal to:

$$E = \overline{w}\,\overline{\rho_v} + \overline{w'\rho_v'}$$

If there is no convergence or divergence of air because of a sloping surface, $\overline{w}$=0 and the first term on the right equals zero. This simplifies the equation to $E = \overline{w'\rho_v'}$. The term on the right hand side is the covariance of vertical velocity and absolute humidity fluctuation, and it provides an expression for the water vapor flux density. Similarly, it can be shown that the sensible heat flux density H (W m^{-2}) is equal to:

$$H = \rho C_p \overline{w'T'}.$$

An eddy covariance system collects high frequency $w'\rho_v'$ and $w'T'$ data and computes the time averaged means so that *E* and *H* can be calculated. Net radiation (R_n) and soil heat flux density (*G*) data are used with *LE*, where *L* is the latent heat of vaporization, and *H* to test accuracy of the measurements. If the measurements are correct, then $R_n - G$ should be approximately equal

to $LE + H$. Evapotranspiration is determined by summing the vapor flux density (E) in kg $m^{-2}s^{-1}$ over a period of time (e.g. 30 minutes) and converting to mm or depth per unit time.

Surface Renewal

Surface renewal is another method that will be used to validate the WRF-ACASA evapotranspiration methods. The surface renewal (SR) method (Paw U and Brunet, 1991) also provides a basis for estimating H and LE and is based on the concept of coherent structures, which are characterized by air sweeps and ejections to and from the surface (Gao et al., 1989). When located in or near the canopy, air parcels heat or cool as sensible heat exchanges with canopy elements. The rate of temperature change over time is related to sensible heat flux density (Paw U et al., 1995). Under unstable conditions, cool air sweeps into a canopy from above and the air parcels are gradually heated by the canopy elements. Hence, temperature traces initially drop sharply which is then followed by a slow rise as the air is heated. Then the warmed air ejects from the canopy and it is again replaced by a sweep of colder air from above. Under stable atmospheric conditions, the pattern is reversed with a sharp temperature increase followed by slow cooling. The air temperature falls slowly as heat is transferred from the air to cooler plant elements. When plotted, temperature traces show ramp-like characteristics, and the mean amplitude (a) and duration of ramp event ($d + s$), where d is the duration of the ramp period and s is the duration of the quiescent period between ramps, can be quantified using structure function analysis (Van Atta, 1977).

Using conservation of energy, Paw U et al. (1995) showed that an expression for H can be derived from the conservation of energy:

$$H = \alpha H' = \alpha\left(\rho C_p \frac{a}{d+s} z\right) \tag{1}$$

where z is the measurement height (m), ρ is the air density (kg m^{-3}) and C_p is the specific heat of the air (J kg^{-1} K^{-1}). The factor H' is the SR sensible heat flux density assuming uniform heating from the ground up to the measurement height (z) and α accounts for unequal heating of the air volume under the temperature sensor (Paw U et al., 1995). The α factor is determined by calculating the slope of the linear regression (through the origin) of H from an accurate independent method such as eddy-covariance using a sonic anemometer versus H' (Snyder et al., 1996; Snyder et al., 1997; Spano et al., 1997a; Spano et al., 2000)

After calculating H', the sensible heat flux density $\alpha H'$ is computed using Eq. (1) and the α factor is calibrated for that vegetation or crop type. For practical purposes, α changes little with stability, wind speed, or other weather factors. LE is determined using measured or estimated Rn and G and $\alpha H'$ in the energy balance equation:

$$LE = R_n - G - \alpha H' \tag{2}$$

The LE calculations are done on a half-hourly basis, and the daily energy fluxes due to R_n, G and LE are computed. Then the mean ET_c for an hour expressed in J m^{-2} s^{-1} is divided by the latent heat of vaporization (L = 2.45 J g^{-1}) and multiplied by 3.6 to obtain the depth of water vaporized (mm).

Task List and Schedule (assuming funding is available January 2006)

Year	Date	Tasks and Deliverables
2006	**Mar. 31**	Order equipment and employ research personnel
	Jun. 30	WRF-ACASA model developed. Personnel trained and experiments begin
	Sep. 30	1st year field experiments completed
	Dec. 31	Field results compared with WRF-ACASA output
2007	**Mar. 31**	Adjustments to WRF-ACASA model and new field experiments planned
	Jun. 30	Field experiments initiated and comparisons are made with WRF-ACASA
	Sep. 30	2nd year field experiments completed
	Dec. 31	Field results compared with WRF-ACASA output
2008	**Mar. 31**	Adjustments to WRF-ACASA model and new field experiments planned
	Jun. 30	Field experiments initiated and comparisons are made with WRF-ACASA
	Sep. 30	3rd year field experiments completed
	Dec. 31	Field results compared with WRF-ACASA output. Final adjustments to WRF-ACASA. Final Report prepared

Section Three: Monitoring and Assessment

Monitoring and assessment is an integral part of this project. The field monitoring procedures are described below. The field monitoring will be used to validate the WRF-ACASA model. To our knowledge, the proposed system to use mesoscale-microscale weather models to forecast crop ET_c does not exist in the world, so there is no baseline for comparison. However, the success of the model can be evaluated by comparing forecast with observed weather data and forecast with measured crop ET_c. If the WRF-ACASA model and delivery system improves accuracy of ET_c estimation, adds a forecast of ET_c and improves the dissemination and use of evapotranspiration-based scheduling, then the project will be successful. The monitoring methodologies, use of the data to evaluate success, external factor effects, data management and estimated costs are given below. At the end of this project, operation of the new CIMIS II system will be gradually be transferred to the California Department of Water Resources.

We will evaluate the accuracy of crop evapotranspiration (ET_c) and landscape evapotranspiration (ET_L) estimates from the WRF-ACASA model. Our main effort is to study crops and landscape vegetation that are not exposed to ET limiting water stress. However, because the ACASA model has a stomatal response model built into it, it has the potential to estimate actual evapotranspiration (ET_a) as well as ET_c. Therefore, ACASA could potentially provide badly needed information on the water usage of crops under regulated deficit irrigation, and natural vegetation in California's summer drought landscape, which would greatly improve water management in the State.

Our ultimate goal is to use remote sensing, WRF and ACASA to estimate ET_c and ET_L and to directly provide that information to growers and irrigation professionals without the need for complicated programs. In our field assessment project, we plan to study several major crop types and natural landscapes within the State including: (1) natural and/or restored wetlands and forests, (2) alfalfa and irrigated pasture, (3) field crops (e.g., cotton, corn, wheat and potatoes), (4) rice, (5) citrus and (6) wine grapes. These crops and landscapes use a considerable portion of the developed water supply in California, and there is considerable potential to improve water management by improving the flow of *ET* information to growers. Studies on these crops and

landscapes will include monitoring ET_c or ET_L and comparing with the WRF-ACASA outputs. In addition, differences in on-farm management strategies and their effects on ET_c will be studied to determine if differences in ET_c due to management exist and can be identified by the WRF-ACASA model. Explanations of the various experiments are presented in the following section.

Wetland ET under Different Climate Regimes in California

Wetlands need substantial water inputs to maintain water quality, flushing wastes, and sustain wildlife and vegetation (Mitsch and Gosselink 2000). California wetlands frequently provide essential habitat for listed sensitive and endangered species. Many wetland refuges in California require inputs from water delivery systems, yet few managers know the true water needs of the wetlands they manage (personal communication, Tracy Slavin, USBR). In order to improve water conservation throughout California, it is important to quantify the water needs of wetland refuges. The only way to do this is to construct water budgets for particular sites. A water budget requires estimation of all inflow and outflow components. In many refuges surface inflows and outflows are already being measured. However, the wetland landscape evapotranspiration (ET_L), which is often the biggest water loss, has rarely been measured in California wetlands, making it difficult to determine the actual water requirements of wetland refuges throughout the state.

The measurement of ET_L in wetlands has a long history (Drexler et al. 2004); however, good estimates of ET_L are few and far between. The reason for this stems from the challenge of measuring ET_L from the varied surfaces that comprise wetlands. For example, wetlands contain open water as well as a diverse assemblage of aquatic and macrophytic vegetation. Incorporating this heterogeneity into measurements of ET_L is challenging. In DWR-funded research conducted on Twitchell Island in the Sacramento Delta (Carbon fluxes study; a collaboration between the USGS and UC Davis), we have combined surface renewal and eddy covariance measurements to incorporate the heterogeneity of the wetland surface into ET_L estimates. Through this research we have learned that ET_L varies not only between surface components but also depending on the direction of winds. When the Delta breeze blows (cool wind) the level of ET_L decreases, but when warm winds blow from the north, ET_L increases. This has important implications for estimating ET_L in wetlands within different climate regimes of California. Currently, little research has been done looking at climate effects on wetland ET_L.

Including a wetland component in this project will provide the following benefits: (1) it will aid in ground-truthing the remote-sensing data, (2) it will inform managers on how to better conserve water in wetland refuges and (3) it will improve the understanding of wetland *ET* under different climate regimes of California. To carry out this part of the project, we will measure wetland ET_L using surface renewal and eddy covariance for a period of two years. We will choose study sites with similar surface cover (i.e., open water, cattails (*Typha* spp.) and tules (*Scirpus* spp.) in three different climate regimes: a warm area with cool wind, a warm area with little wind, and a warm area with warm wind. We will evaluate the ability of the WRF-ACASA model to estimate the ET_L in the different climates. In addition, we will compute the landscape coefficient (K_L) values to estimate ET_L from ET_o and we will publish our results in peer-reviewed journals and post the K_L values for *Typha* and *Scirpus* species on relevant web sites. Wetland managers will be able to use the WRF-ACASA model estimates of ET_L directly or ET_o and the developed K_L values to estimate ET_L from refuges dominated by these species. We hope to determine K_L values for additional wetland plant species in the coming years. This experiment will require the purchase of two eddy covariance systems and two surface renewal systems. An additional eddy covariance and surface renewal station will be provided by a cooperating agency

(USGS). The experiment will require one full time Post Doctoral researcher and support from the US Geological Survey personnel with wetland expertise.

Wine grape Vineyards

Three sites will be established to study evapotranspiration of drip irrigated grape vineyards with different planting density and trellising systems. Most winegrape growers have changed to drip irrigation and the trend now is to change to more dense plantings. Since high density vineyard planting is expanding rapidly and the ET_c from denser plantings is unknown, our goal is to study both the traditional and high density plantings to determine differences in water use and relate them to the WRF-ACASA model. In addition, we will place an eddy flux station in a non-level vineyard to study the difference in ET_c from level land and from vineyards on sloping land. In water balance scheduling, the effects of land slope and aspect on ET_c and K_c values have been relatively ignored. Since many vineyards are planted in undulating terrain, there is clearly a need to study slope and aspect effects on ET_c. Growers using high frequency irrigation methods (e.g., drip irrigation) were found to be the most likely to use CIMIS (Snyder et al., 1996) and grape vineyard planting is expanding rapidly. Therefore, it is extremely important to work with this crop in the CIMIS II project. This experiment will require three surface renewal stations and one eddy covariance station. One Post Doctoral researcher (1.0 FTE all year) is required for this research.

Alfalfa and Irrigated Pasture

Alfalfa and irrigated pasture are two of the largest water consuming crops in California and good information on the water usage is critically needed to improve management. Because of multiple cuttings, it is very difficult to estimate the ET_c of alfalfa because the crop coefficients change during each cycle. In fact, alfalfa is a high water user and few growers if any use CIMIS to schedule irrigation and improve efficiency. This is mainly due to the complexity of estimating K_c values to use as the canopy changes. The WRF-ACASA combination model may greatly improve our ability to estimate ET_c directly and, therefore, it can provide the data in a format that is more easily used by growers. In this experiment, we will need two eddy covariance system and two surface renewal stations to collect field data. The eddy covariance systems are used for calibration of the surface renewal stations and to collect data that are valid regardless of the canopy height. The calibration of the surface renewal estimates varies as the canopy changes, so calibration relative to canopy height must be developed before using the surface renewal stations to measure ET_c. One graduate student researcher (0.5 FTE academic year, 1.0 FTE summer) is needed for this project. One junior researcher (1.0 FTE all year) will work on this project and the field crops project.

Field Crops (cotton, corn, wheat and potatoes)

Field crop ET_c and its relationship to the WRF-ACASA model will be field tested mainly using the lysimeters facilities at UC Davis; however, there will also be additional measurements in commercial fields or at UC field stations. Each of the three years, we will plant two different crops in and around the lysimeters to provide ground truth data for the WRF-ACASA model. In addition, we will use the lysimeters as a test against eddy covariance and surface renewal measurements. These experiments will require one eddy covariance and two surface renewal station for experiments in commercial fields and at field stations. This experiment will require one graduate student researcher (0.5 FTE academic year and 1.0 FTE summer) and one junior specialist (1.0 FTE all year).

Rice

Rice ET_c will be measured for three different irrigation strategies in another project proposal for Proposition 50 funding. In that project, the ET_c of traditional rice management will be compared with ET_c of rice that is planted and then the water is removed temporarily and then re-flooded for the remainder of the season. This will be done on tilled and non-tilled soil. The objective is to determine if removing the water will reduce water usage by the rice. Based on earlier experiments, it was found that the K_c for rice decreases as the rice plants grow and shade the water from direct sunlight. Therefore, this management may lead to reduced water use by the rice crop. Assuming that the project if funded, the ET_c data will be compared with the WRF-ACASA model results in this project. If the separate rice project is not funded, then comparisons with WRF-ACASA will not be possible.

Citrus orchards

Recently, several years of experiments have shown that the K_c used for citrus was too low. The difference lies in the fact that citrus trees were infrequently irrigated with furrows when the old K_c values were developed. Now the orchards are frequently irrigated by microsprinkler and, as a result, the trees are more vigorous and there is more soil evaporation than in the past. In the recent studies, it was noted that the K_c values changed dramatically depending on pruning and on the tree canopy size. Also, it is possible that some ET_c differences exist because of row orientation. The row orientation was not mentioned in the old literature and only east-west rows were studied in the recent research. The K_c values were developed in Central Valley experiments and their validity in coastal regions and in the desert are unknown. Therefore, our goals are to make comparisons between orchards with different row orientations and to study K_c values of orchards in coastal and desert climates. In addition, the ET_c measurements will be used to validate the WRF-ACASA model. In these experiments, we would need one eddy covariance system and two surface renewal systems. A graduate student researcher (0.5 FTE academic year and 1.0 FTE summer) and a 1.0 FTE junior specialist will be needed for this project.

Other Crops

We will negotiate with the USDA and UC researchers at the Kearney Ag Center to compare WRF-ACASA with their lysimeters measurements.

Other Landscapes and Applications

In addition to sites that we monitor to ground truth the WRF-ACASA model, we can also test the model against natural ecosystem data that are available from AmeriFlux monitoring sites in California. These are research sites that operate long-term eddy covariance measurement systems. These include grass rangeland and oak forests in the Sierra Nevada foothills and forests in several locations. While these locations are not irrigated, the ability to test the WRF-ACASA model against monitored ET_L and CO_2 fluxes at these sites may provide us with the ability to obtain wide-spread spatial information on the environmental status of our natural resources. For example, the information would be extremely valuable for wildfire prediction. There is no funding request for the other landscapes and applications project.

C. QUALIFICATIONS OF THE APPLICANTS AND COOPERATORS

C.1. Resumes of project manager and co-investigators

The project managers are all faculty, specialists and farm advisors with the University of California except for Dr. Judy Drexler, with the US Geological Survey, who is an expert on wetlands. Resumes of the project manager and co-investigators are provided in attachment 6.

C.2. Role of external cooperator

Dr. Judy Drexler is a research scientist with the US Geological Survey. She is the only non-University investigator participating in this project, and she is included because of her experience and knowledge pertaining to wetlands. Because wetlands are important considerations in California's water resource planning, especially in the Delta, we feel it is extremely important to include a study of wetland evapotranspiration in the project.

D. OUTREACH, COMMUNITY INVOLVEMENT, AND ACCEPTANCE

This project includes one UC Cooperative Extension Specialist and two UC Farm Advisors. Since their positions are primarily directed to dissemination of new and existing technologies, outreach will be a strong component of the project. The principle investigator has given hundreds of grower presentations and prepared considerable written materials to encourage the use of the original CIMIS network. With CIMIS II, the extension activities will be further increased. In addition, all University of California faculty have an outreach component to their positions and extending information on the results of CIMIS II will be a priority. Although it is difficult to estimate the number of people expected to receive training CIMIS II, we expect that this project will have a bigger impact on California than the original CIMIS project.

E. INNOVATION

This project is extremely innovative, using cutting edge knowledge to again put California at the forefront of efficient irrigation management. To our knowledge, a similar system to the WRF-ACASA model does not exist anywhere in the world. This project will eliminate the need for crop coefficients, which a major limitation to grower adoption. It will provide a forecast as well as near-real time crop evapotranspiration (ET_c) data rather than only near-real time reference evapotranspiration (ET_o) data as is currently provided by CIMIS. This will provide the information needed to do irrigation scheduling by growers and landscape professionals using high frequency irrigation. It will provide site specific information for any location in the state, which will greatly reduce the need for large numbers of CIMIS stations and the problems associated with non-ideal station locations. It is anticipated that the CIMIS II will reduce CIMIS operational costs and savings to the State will pay for this project within a few years. The information simplification will enhance grower and landscape professional adoption and use of *ET* information, which will greatly benefit California.

F. BENEFITS AND COSTS

F.1. Potential benefits of study and estimates of total expected water savings

The CIMIS II project has the potential to greatly improve water use efficiency of irrigation management in California. The original CIMIS network costs about $850,000 per year to operate, but increased profits alone have resulted in more than $64,000,000 per year in benefits to California growers. It is likely that CIMIS II will significantly reduce the operational costs by reducing the need for large numbers of weather stations, while improving coverage of the State, especially in urban areas. In addition, it is expected that CIMIS II will significantly increase the number of growers and landscape professionals using ET for scheduling and hence could result in large increases in water savings statewide. It is not unreasonable to expect that CIMIS II will double the water savings and profits realized by the original CIMIS project.

F.2. Project Costs (Budget)

The budget for this project is presented in Attachment 1. The overall funding request is $3,587,859, which will be divided over the three years of the project. The details of the expenditures are presented below.

a. Salaries and Wages

$1,443,994

b. Fringe Benefits

$330,101

c. Supplies

$113,154

d. Equipment

$335,874

e. Consulting Services

Consulting services of $186,098 are broken down by task in attachment 1.

f. Travel

Costs of $315,000 divided over three years for travel to research sites and presentations of findings to the co-investigators, cooperators, and researchers during meetings and conferences.

g. Other administrative costs

Indirect costs for state agency of 25% are charged to all items but equipment and graduate student remission fees giving a total overhead of $552,062. Indirect costs for consulting services are the 25% of the first $25,000 or $6,250.

h. Planning/Design/Engineering

i. Materials/Installation/Implementation

j. Other costs

Graduate student remission fees of $299,326 for the six graduate student researchers. Note that these employees require only 1.5% benefits and the remission fee is not included in overhead calculations.

k. Total Costs

$3,587,859

The project costs are separated into components in Table C-1 (below). Further details on the budget are provide in Attachments 1-5.

Table C-1: Project Costs (Budget) in Dollars)

	Category (I) Administration[1]	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)
	Salaries, wages	$1,443,994	0	$1,443,994	$0	$1,443,994
	Fringe benefits	$330,101	0	$330,101	$0	$330,101
	Supplies	$113,154	0	$113,154	$0	$113,154
	Equipment	$335,874	0	$335,874	$0	$335,874
	Consulting Services	$186,098	0	$186,098	$0	$186,098
	Travel	$315,000	0	$315,000	$0	$315,000
	Other	$863,638	0	$863,638	$0	$863,638
(a)	Total Administration Costs	$3,587,859		$3,587,859	$0	$3,587,859
(b)	Planning/Design/Engineering	$0	0	$0	$0	$0
(c)	Equipment Purchases/Rentals/ Rebates/Vouchers	$0	0	$0	$0	$0
(d)	Materials/Installation/Implementation	$0	0	$0	$0	$0
(e)	Implementation Verification	$0	0	$0	$0	$0
(f)	Project Legal/License Fees	$0	0	$0	$0	$0
(g)	Structures	$0	0	$0	$0	$0
(h)	Land Purchase/Easement	$0	0	$0	$0	$0
(i)	Environmental Compliance/Mitigation/Enhancement	$0	0	$0	$0	$0
(j)	Construction	$0	0	$0	$0	$0
(k)	Other (Specify)	$0	0	$0	$0	$0
(l)	Monitoring and Assessment	$0	0	$0	$0	$0
(m)	Report Preparation	$0	5	$0	$0	$0
(n)	**TOTAL**	$3,587,859		$3,587,859	$0	$3,587,859
(o)	Cost Share -Percentage				0	100

1- excludes administration O&M.

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Attachment 1

Below is the cost breakdown for the consultant USGS contribution to the wetland project.

Budget (anticipating work to be done FY 06 – 08)

Budget item	**FY 2006**	**FY 2007**	**FY 2008**
Salary and benefits for JZD (25% time)	$25,330	$26,548	$ 27,278
Travel	$ 3,000	$ 3,000	$ 2,500
Gas	$ 500	$ 500	
Supplies	$ 1,500	$ 1,000	$ 500
Reports Assessment	$ 2,123	$ 2,173	$ 2,119
Project Contingency Assessment	$ 1,623	$ 1,661	$ 1,620
Science Program Direct Charge	$ 2,132	$ 2,182	$ 2,128
Direct Charges for management personnel	$ 4,898	$ 5,014	$ 4,890
Overhead	$19,696	$21,031	$ 21,150
Yearly Cost	$60,802	$63,110	$ 62,186
TOTAL COST			$186,098

UCD overhead on the USGS component is 25% of the first $25,000 = $6250

Attachment 2. Equipment and Lysimeter Management Costs

Number	Item	Cost	Total
7	Eddy Covariance Systems	$35,403	$247,821
11	Surface Renewal Systems	$5,229	$57,519
	Tax & Shipping		$30,534
	Total		$335,874

Estimated cost for an Eddy Covariance System

Number	Model	Item	Cost	Total
1	CR5000	Datalogger	4570.00	4570.00
1	16765	CSAT3 Sonic Anemometer	7700.00	7700.00
1	10080	TC mount cover	30.00	30.00
1	16764	CSAT3 Case	600.00	600.00
1	HMP45C-L10	Visala T&RH sensor	550.50	550.50
1	CS7500	Li-cor Open path Analyzer	13400.00	13400.00
1	KH20	Krypton Hygrometer	4900.00	4900.00
1	UT018	Tower Mounting Bracket	95.00	95.00
1	14118	Mount for CSAT3/KH20	55.00	55.00
1	6880	UT018 Wind Sentry/ IRGA bracket	60.00	60.00
1	1017	3/4 x 3/4 Crossover NuRail #10	13.00	13.00
		subtotal		31973.50
1	CM10	10' tower	345	345
1	10844	guy wires for tower	84	84
1	7839	Mounting bracket	35	35
1	15875	Micrologger enclosure	195	195
1	msx10	Solar collector	200	200
1	BP24	Logger battery	140	140
1	Q7_1-L30	REBS net radiometer with 30' cable	990	990
3	HFT3-L30	REBS heat flux plate with 30' cable	320	960
3	TCAV-L30	Soil temp averaging sensor with 30' cable	160	480
		subtotal		3429

Estimated cost for a Surface Renewal Station

Number	Model	Item	Cost	Total
1	CR10X	Datalogger	1190.00	1190.00
4	FW3	Thermocouples	95.00	380.00
2	FWC-20	Thermocouple cable	52.40	104.80
1	FW/ENC	carrying case	35.00	35.00
1	15663	Rs232 Interface	90.00	90.00
		subtotal		1799.80
1	CM10	10' tower	345	345
1	10844	Guy wires for tower	84	84
1	7839	Mounting bracket	35	35
1	15875	Micrologger enclosure	195	195
1	msx10	Solar collector	200	200
1	BP24	Logger battery	140	140
1	Q7_1-L30	REBS net radiometer with 30' cable	990	990
3	HFT3-L30	REBS heat flux plate with 30' cable	320	960
3	TCAV-L30	Soil temp averaging sensor with 30' cable	160	480
		subtotal		3429
		Total		5228.80

Attachment 3. Breakdown of project budget by year.

Item	2006	2007	2008	Total
Salaries & Benefits	$572,267	$594,965	$606,864	$1,774,095
Supplies	$64,718	$24,218	$24,218	$113,154
Travel*	$105,000	$105,000	$105,000	$315,000
Employee Recruitment	$4,000	$1,000	$1,000	$6,000
Sum Indirect Costs	$745,985	$725,183	$737,082	$2,208,249
Overhead (25%)	$186,496	$181,296	$184,270	$552,062
Subtotal	$932,481	$906,478	$921,352	$2,760,312
Consulting (USGS)	$60,802	$63,110	$62,186	$186,098
Overhead (25% of $25,000)	$6,250			$6,250
Subtotal Indirect Costs and Overhead	$999,533	$969,588	$983,538	$2,952,660
Equipment	$335,874			$335,874
Remission Fees	$91,311	$99,529	$108,486	$299,326
Subtotal Direct Costs	$427,185	$99,529	$108,486	$635,200
Total Cost	$1,426,718	$1,069,117	$1,092,024	$3,587,859

* $7000 per employee per year

Attachment 4. Details on employee salaries.

Salary Details			Academic Year					Summer					
2006		Full Salary	FTE	Mon	Benefits.	Salary	Benefits	FTE	Mon	Benefits	Salary	Benefits	Rem.Fee
Project Work	Employee	$/mon			%	$	$			%	$	$	$
WRF	Post Doc. Res.	$3,443.52	1.00	9	31	$30,992	$9,607	1.00	3	31	$10,331	$3,202	
	Grad St. Res.	$3,209.94	0.46	9	1.5	$13,289	$199	0.92	3	3	$8,859	$266	$25,680
ACASA	Post Doc. Res.	$3,443.52	1.00	9	31	$30,992	$9,607	1.00	3	31	$10,331	$3,202	
	Grad St. Res.	$3,209.94	0.46	9	1.5	$13,289	$199	0.92	3	3	$8,859	$266	$25,680
Remote Sensing	Post Doc. Res.	$3,443.52	1.00	9	31	$30,992	$9,607	1.00	3	31	$10,331	$3,202	
	Grad St. Res.	$3,209.94	0.46	9	1.5	$13,289	$199	0.92	3	3	$8,859	$266	$9,988
	Junior Spec.	$2,638.74	1.00	9	31	$23,749	$7,362	1.00	3	31	$7,916	$2,454	
Wetlands	Post Doc. Res.	$3,443.52	1.00	9	31	$30,992	$9,607	1.00	3	31	$10,331	$3,202	
Grapevines	Post Doc. Res.	$3,443.52	1.00	9	31	$30,992	$9,607	1.00	3	31	$10,331	$3,202	
Alfalfa-Pasture	Grad St. Res.	$3,209.94	0.46	9	1.5	$13,289	$199	0.92	3	3	$8,859	$266	$9,988
	Junior Spec.	$2,638.74	1.00	9	31	$23,749	$7,362	1.00	3	31	$7,916	$2,454	
Field Crops	Grad St. Res.	$3,209.94	0.46	9	1.5	$13,289	$199	0.92	3	3	$8,859	$266	$9,988
	Junior Spec.	$2,638.74	1.00	9	31	$23,749	$7,362	1.00	3	31	$7,916	$2,454	
Citrus-Vegetables	Grad St. Res.	$3,209.94	0.46	9	1.5	$13,289	$199	0.92	3	3	$8,859	$266	$9,988
	Junior Spec.	$2,638.74	1.00	9	31	$23,749	$7,362	1.00	3	31	$7,916	$2,454	
2007		Full Salary	FTE	Mon	Benefits	Salary	Benefits	FTE	Mon	Benefits	Salary	Benefits	Rem.Fee
WRF	Post Doc. Res.	$3,512.39	1.00	9	31	$31,612	$9,800	1.00	3	$31	$10,537	$3,267	
	Grad St. Res.	$3,274.14	0.46	9	1.5	$13,555	$203	0.92	3	$3	$9,037	$271	$27,991
ACASA	Post Doc. Res.	$3,512.39	1.00	9	31	$31,612	$9,800	1.00	3	$31	$10,537	$3,267	
	Grad St. Res.	$3,274.14	0.46	9	1.5	$13,555	$203	0.92	3	$3	$9,037	$271	$27,991
Remote Sensing	Post Doc. Res.	$3,512.39	1.00	9	31	$31,612	$9,800	1.00	3	$31	$10,537	$3,267	
	Grad St. Res.	$3,274.14	0.46	9	1.5	$13,555	$203	0.92	3	$3	$9,037	$271	$10,887
	Junior Spec.	$2,870.46	1.00	9	31	$25,834	$8,009	1.00	3	$31	$8,611	$2,670	
Wetlands	Post Doc. Res.	$3,512.39	1.00	9	31	$31,612	$9,800	1.00	3	$31	$10,537	$3,267	
Grapevines	Post Doc. Res.	$3,512.39	1.00	9	31	$31,612	$9,800	1.00	3	$31	$10,537	$3,267	
Alfalfa-Pasture	Grad St. Res.	$3,274.14	0.46	9	1.5	$13,555	$203	0.92	3	$3	$9,037	$271	$10,887
	Junior Spec.	$2,870.46	1.00	9	31	$25,834	$8,009	1.00	3	$31	$8,611	$2,670	
Field Crops	Grad St. Res.	$3,274.14	0.46	9	1.5	$13,555	$203	0.92	3	$3	$9,037	$271	$10,887
	Junior Spec.	$2,870.46	1.00	9	31	$25,834	$8,009	1.00	3	$31	$8,611	$2,670	
Citrus-Vegetables	Grad St. Res.	$3,274.14	0.46	9	1.5	$13,555	$203	0.92	3	$3	$9,037	$271	$10,887
	Junior Spec.	$2,870.46	1.00	9	31	$25,834	$8,009	1.00	3	$31	$8,611	$2,670	

Attachment 4. Details on employee salaries (continued)

Salary Details			Academic Year					Summer					
2008		Full Salary	FTE	Mon	Benefits	Salary	Benefits	FTE	Mon	Benefits	Salary	Benefits	Rem.Fee
Project Work	Employee	$/mon			%	$	$			%	$	$	$
WRF	Post Doc. Res.	$3,582.64	1.00	9	31	$32,244	$9,996	1.00	3	31	$10,748	$3,332	
	Grad St. Res.	$3,339.62	0.46	9	1.5	$13,826	$207	0.92	3	3	$9,217	$277	$30,510
ACASA	Post Doc. Res.	$3,582.64	1.00	9	31	$32,244	$9,996	1.00	3	31	$10,748	$3,332	
	Grad St. Res.	$3,339.62	0.46	9	1.5	$13,826	$207	0.92	3	3	$9,217	$277	$30,510
Remote Sensing	Post Doc. Res.	$3,582.64	1.00	9	31	$32,244	$9,996	1.00	3	31	$10,748	$3,332	
	Grad St. Res.	$3,339.62	0.46	9	1.5	$13,826	$207	0.92	3	3	$9,217	$277	$11,866
	Junior Spec.	$2,927.87	1.00	9	31	$26,351	$8,169	1.00	3	31	$8,784	$2,723	
Wetlands	Post Doc. Res.	$3,582.64	1.00	9	31	$32,244	$9,996	1.00	3	31	$10,748	$3,332	
Grapevines	Post Doc. Res.	$3,582.64	1.00	9	31	$32,244	$9,996	1.00	3	31	$10,748	$3,332	
Alfalfa-Pasture	Grad St. Res.	$3,339.62	0.46	9	1.5	$13,826	$207	0.92	3	3	$9,217	$277	$11,866
	Junior Spec.	$2,927.87	1.00	9	31	$26,351	$8,169	1.00	3	31	$8,784	$2,723	
Field Crops	Grad St. Res.	$3,339.62	0.46	9	1.5	$13,826	$207	0.92	3	3	$9,217	$277	$11,866
	Junior Spec.	$2,927.87	1.00	9	31	$26,351	$8,169	1.00	3	31	$8,784	$2,723	
Citrus-Vegetables	Grad St. Res.	$3,339.62	0.46	9	1.5	$13,826	$207	0.92	3	3	$9,217	$277	$11,866
	Junior Spec.	$2,927.87	1.00	9	31	$26,351	$8,169	1.00	3	31	$8,784	$2,723	
Sum over Years		Full Salary	FTE	Mon	Benefits	Salary	Benefits	FTE	Mon	Benefits	Salary	Benefits	Rem.Fee
WRF	Post Doc. Res.					$94,847	$29,403				$31,616	$9,801	
	Grad St. Res.					$40,670	$610				$27,113	$813	$84,182
ACASA	Post Doc. Res.					$94,847	$29,403				$31,616	$9,801	
	Grad St. Res.					$40,670	$610				$27,113	$813	$84,182
Remote Sensing	Post Doc. Res.					$94,847	$29,403				$31,616	$9,801	
	Grad St. Res.					$40,670	$610				$27,113	$813	$32,741
	Junior Spec.					$75,934	$23,539				$25,311	$7,846	
Wetlands	Post Doc. Res.					$94,847	$29,403				$31,616	$9,801	
Grapevines	Post Doc. Res.					$94,847	$29,403				$31,616	$9,801	
Alfalfa-Pasture	Grad St. Res.					$40,670	$610				$27,113	$813	$32,741
	Junior Spec.					$75,934	$23,539				$25,311	$7,846	
Field Crops	Grad St. Res.					$40,670	$610				$27,113	$813	$32,741
	Junior Spec.					$75,934	$23,539				$25,311	$7,846	
Citrus-Vegetables	Grad St. Res.					$40,670	$610				$27,113	$813	$32,741
	Junior Spec.					$75,934	$23,539				$0	$0	
Total											$1,443,994	$330,101	$299,326

Attachment 5. Costs for Davis lysimeters operation each summer.

Main Field Operations	Tractor						Implement				Labor			Materials				Total
	#	Use		Rate		Cost	#	Use	Rate	Cost	Hrs	Rate	Cost	Water	Fert.	Seed	Misc	
		Hrs Ac	Dys	Hour	Day			Dys	Day									
Spring-tooth	7	8	1	$25	$25	$225	$1,212	1	$60	$60	8	$35	$280					$565
Disc	68	12	2	$32	$32	$448	$1,222	2	$75	$150	12	$35	$420					$1,018
Landplane	68	8	1.5	$32	$32	$304	$1,420	1.5	$60	$90	8	$35	$280					$674
Disc	68	12	2	$32	$32	$448	$1,222	2	$75	$150	12	$35	$420					$1,018
Fertilize	16	6	1	$13	$13	$91	$2,490	1	$65	$65	6	$35	$210		$750			$1,116
List	29	6	1	$18	$18	$126		1			6	$35	$210					$336
Bed prep	16	6	1	$13	$13	$91		1			6	$35	$210					$301
Pre-irrigation											27	$10	$270	$185				$455
Herbicide application	61	10		$7		$71					4	$35	$140				$350	$561
Herbicide incorporation	29	8	1	$18	$18	$162		1			8	$35	$280					$442
Pre-plant cultivation	29	8	1	$18	$18	$162		1			8	$35	$280					$442
Planting	16	10	1.5	$13	$13	$150		1.5			10	$35	$350			$300		$800
Irrigation											27	$10	$270	$154				$424
Cultivation	28	12	2	$18	$18	$252		2		$0	12	$35	$420					$672
Irrigation											27	$10	$270	$154				$424
Cultivation	28	8	1	$18	$18	$162		1		$0	8	$35	$280					$442
Irrigation											27	$10	$270	$154				$424
Irrigation											27	$10	$270	$154				$424
Pesticide application	61	10		$7		$71					4	$35	$140				$350	$561
Chopping	28	10	1.5	$18	$18	$207	$2,930	1.5	$90	$135	10	$35	$350					$692
Stubble disc	68	10	1.5	$32	$32	$368	$1,222	1.5	$85	$128	10	$35	$350					$846
Main Field Operations Total						$3,338				$778			$5,970	$803	$750	$300	$700	$12,638

Attachment 5. Costs for Davis lysimeters operation each summer (continued).

Lysimeter					
Pre-plant Preparation	27	$10	$270		
Planting	12	$10	$120		
Irrigation	27	$10	$270		
Cultivation	36	$10	$360		
Post crop maintenance	36	$10	$360		
Service, calibration				$1,000	
Update load cell, electronics				$1,700	
Lysimeters Total			$1,380	$2,700	$4,080
Grand Total					**$16,718**

Attachment 6. Curriculum Vitae of Investigators

CURRICULUM VITAE

Richard L. Snyder

Biometeorology Specialist
University of California
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Education

Iowa State University, Ph.D. Agricultural Climatology, 1980; Iowa State University, M.S., Agricultural Climatology, 1978; University of Northern Iowa, B.A., Mathematics, 1971; North Iowa Area Community College, A.A., Mathematics, 1969

Experience

1980 - Present - Biometeorologist Specialist;University of California, Department of Land, Air and Water Resources, Davis, California

Professional Affiliation

American Meteorological Society
International Society for Horticultural Science
International Society of Biometeorology

Major Research and Teaching Activities

During my employment with the University of California, my main research and teaching activities were related to (1) testing and developing methods for estimating evapotranspiration, (2) irrigation scheduling, and (3) freeze protection of crops. In recent years, my research activities have expanded to include studies on (1) wildfire risk and (2) energy and carbon fluxes over restored wetlands.

For the past few years, we have conducted research to measure evapotranspiration and carbon fluxes from a restored wetland in conjunction with colleagues from the US Geological Survey. This research effort compliments the USGS efforts to monitor carbon balance in restore wetlands. The ultimate goal is to determine if the restored wetland is a source or sink of CO_2 and to determine the evapotranspiration of the wetland. This information is needed to insure drinking water quality for water transfers to Southern California and to make decisions on future management of the Sacramento-San Joaquin River Delta to minimize water losses. The carbon flux information is needed to determine if future Delta management will be beneficial or detrimental to the global carbon balance.

During the past 10 years, I have worked extensively with colleagues to develop the new "Surface Renewal" method for estimating sensible heat flux density using low-cost instrumentation. This has greatly facilitated our estimation of crop evapotranspiration for tomatoes, maize, sunflowers, grapevines, citrus and rice. The goal is to use this information to improve irrigation management and water resource planning in California.

In my early work at the University of California, I was the principal investigator on the California Irrigation Management Information System (CIMIS) research and development project. In this three-year project, a network of 43 electronic weather stations was established to

gather data for the calculation of reference evapotranspiration. In addition, field testing of the ET_o data for use in irrigation scheduling, modeling and improving methods to access irrigation efficiency, analyzing the economic benefits of using CIMIS ET_o for irrigation scheduling, and studies on encouraging the adoption and use of CIMIS were conducted. More than 17 researchers were employed on the three-year project at a cost of approximately $3,500,000. Today there are about 150 electronic weather stations in the network. It is estimated that CIMIS saves California growers about $64 million per year from water savings and increased production. Following on this work, I have more recently been involved in the development of weather simulation application programs for use in long-term water resource planning in California.

As of September 2004, I have authored or co-authored 83 published or in-press refereed scientific papers on a wide variety of topics including frost protection, irrigation scheduling, wetlands ET and carbon fluxes, plant phenology, long-term water resource planning, surface renewal, etc. Reviewed publications that are related to this project are listed below.

Short list of Reviewed Publications (related to this topic)

Drexler, J.Z., Snyder, R.L., Spano, D. and Paw U, K.T. 2003. A Review of Models and Micrometeorological Methods used to Estimate Wetland Evapotranspiration. *Hydrologic Processes*, pp. 54 (in press).

Faber, B.A. and R.L. Snyder. 1988. Extension activities needed to address the limited use of evapotranspiration. J. of Agronomic Education, Vol. 19, No. 1, pp. 7-13.

Paw U, K.T., R.L. Snyder and D. Spano. 2003. Surface renewal. In: Micrometeorology in Agricultural Systems. Hatfield, J.L. and Baker, J.L (Eds.). ASA Monograph No. XX, ASA-CSSA-SSSA, Madison, WI. (in press).

Shaw, R.H. and R.L. Snyder. 2003. Evaporation and eddy covariance. In: *Encyclopedia of Water Science*. Stewart, B.A. and Howell, T. (Eds.). Marcel Dekker Inc., New York. Marcel Dekker Inc., New York. DOI: 10.1081/E-EWS 120010306.

Snyder, R.L. and W.O. Pruitt. 1992. Evapotranspiration data management in California. Irrigation and Drainage Session Proceedings Water Forum 1992, ASCE. August 2-6, 1992, Baltimore, MD., pp.128-133.

Snyder, R.L., D. Spano and K.T. Paw U. 1996. Surface renewal analysis for sensible and latent heat flux density. Boundary Layer Meteorol. 77: 249-266.

Snyder, R.L., M.A. Plas and J.I. Grieshop. 1996. Irrigation methods used in California: a grower survey. J. of Irrig. and Drain. Eng., Vol. 122, No. 4: 259-262.

Spano, D., R.L. Snyder, P. Duce and K.T. Paw U. 1997. Surface renewal analysis for sensible heat flux density using structure functions. Agric. & For. Meteorol. 86 (1997) 259-271.

Spano, D., R.L. Snyder, P. Duce and K.T. Paw U. 2000. Estimating sensible and latent heat flux densities from grapevine canopies using surface renewal. Agric. & For. Meteorol. 104 (2000): 171-183.

Snyder, R.L. 2000. Reference evapotranspiration and crop coefficients. Proceedings of the Agricultural Weather System Workshop. Hubbard, K.G. and M.V.K Sivakumar (eds.), Lincoln, Nebraska, March 6-10, 2000 High Plains Climate Center, Univ. of Nebraska-Lincoln and World Meteorol. Organization, Geneva. p. 149-161.

Ventura, F., B.A. Faber, K. Bali, R.L. Snyder, D. Spano, P. Duce and K.F. Schulbach. 2001. Model for estimating evaporation and transpiration from row crops. J. of Irrig. and Drain. Engng. 127(6): 339-345.

CURRICULUM VITAE
Susan L. Ustin

Professor of Environmental and Resource Science
Department of Land, Air, and Water Resources
Director, Center for Spatial Technologies and Remote Sensing (CSTARS),
Director, California Space Institute Remote Sensing of Agriculture, Nat. Res. and Environ.
Director, DOE's Western Regional Center for Global Environmental Change
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Education

University of California, Davis, Ph.D. Botany, 1983; California State University, Hayward, M.A. Biology, 1978; California State University, Hayward, B.S. Biology, 1974

Professional Experience

1995-2001 Associate Director, DOE's Western Regional Center for Global Environmental Change (WESTGEC), University of California, Davis
1995-present, Director, U. C. Davis Space Grant Program
1999-present Professor of Environmental and Resource Science, Dept. of L.A.W.R., U.C., Davis
1996-1999 Associate Professor of Resource Science, Dept. of L.A.W.R., U.C., Davis
1991-1996 Assistant Professor of Resource Science, Dept. of L.A.W.R., U.C., Davis
1990-1991 Assistant Research Resource Scientist, Dept. of L.A.W.R., U.C., Davis
1990-1992 Research Associate with NASA Ames Research Center, Moffett Field, CA

Honors

1992 - IEEE Geoscience and Remote Sensing Society Transactions Prize Paper Award.
2002 – Elected Fellow, The Remote Sensing and Photogrammetry Society
2004 – Outstanding Service, American Society of Photogrammetry and Remote Sensing
2004 – Elected Senior Member, Institute of Electrical and Electronic Engineers
2004 – SERDP Conservation Project of the Year

Panels and Professional Committees

NASA MODIS Science Team Member, 2004-present.
NPOESS Science Advisory Board, Northrop-Grumman, 2002-present.
U.C. Davis Representative to the University Corporation for Atmospheric Research, 1993-present
Resource21 Science Advisory Board for Landsat LDCM Mission, 2000-2002.
Advisory Board Member, Environmental (Remote Sensing) Baselining Initiative, Chevron, Corp. 1999-2002.
Executive Committee, U.C. California Space Institute 1993-2002
Member, National Research Council, Committee on Earth Studies, Space Studies Board, Commission on Physical Sciences, Mathematics and Applications. 1999. Review of NASA's Post-2002 Plan.
Executive Committee Member and Vice Chair, for the UC Digital Media Innovation Program (DiMI), 1998-2002
UC Davis Advisor for the NASA Ames Associates Internship Program, 1997-2000
Member, National Research Council, Committee on Earth Studies, Space Studies Board, Commission on Physical Sciences, Mathematics and Applications. 1997-2000. Review of the NPOESS Program.
Member, National Research Council, Ecosystems Panel, Board of Agriculture, Commission on

Geosciences, Environment and Resources and the Commission on Life Sciences. 1997-1999. Review of the Ecosystems program in the U.S. Global Change Research Program.

Member, National Research Council, Board of Agriculture. 1995-1997. Assessing Crop Yield: Site-specific farming, information systems, and research opportunities.

Science Team Member, Sierra Nevada Ecosystem Study (U.S. Congress Report), 1993-1996.

Science Team Member, NASA Earth Observing System (EOS), Interdisciplinary Science Team, Atmosphere-Biosphere Interactions, 1990-present

Chair, Graduate Ecosystem and Landscape Ecology Program (Ecology Grad. Group, 1991-97)

Publications: 115 reviewed articles; >100 non-reviewed articles; >100 abstracts

Kasischke, E.S., S. Goetz, M. Hansen, M. Ozdogan, J. Rogan, S.L. Ustin and C.E. Woodcock, Temperate and boreal forests. 2004. In: Manual of Remote Sensing Vol. 4. Remote Sensing of Natural Resource Management and Environmental Monitoring (S.L. Ustin, vol. ed.). ASPRS. John Wiley and Sons, New York, pages 147-238.

Li, L. and S.L. Ustin, 2004. Application of AVIRIS data in detection of oil-induced vegetation stress at Jornada, New Mexico, Remote Sensing of Environment (accepted).

Riano, D., E. Meier, B. Allgöwer, E. Chuvieco, S.L. Ustin. 2003. Modeling airborne laser scanning data for the spatial generation of critical forest parameters in fire behavior modeling. Remote Sensing of Environment 86:177-186.

Riano, D., E. Chuvieco, S. Condes, J. Gonzalez-Matesanz, and S.L. Ustin. 2004. Generation of crown bulk density for *Pinus sylvestris* L. from LIDAR. Remote Sensing of Environment 92(3):345-352.

Roberts, D.A., S.L. Ustin, S. Ogunjemiyo, J. Greenberg, S.Z. Dobrowski, J. Chen, and T.M. Hinckley. 2004. Spectral and structural measures of northwest forest vegetation at leaf to landscape scale. Ecosystems 7(5):545-562.

Whiting, M.L., L. Li, and S.L. Ustin, 2004. Predicting water content using Gaussian model of soil spectra. Remote Sensing of Environment 89:535-552.

Wilson, M.D., S.L. Ustin, and D.M. Rock. 2004. Comparison of support vector machine classification to partial least squares dimension reduction with logistic discrimination of hyperspectral data. Transactions on GeoScience and Remote Sensing 42 (5):1088-1095.

Underwood, E. and S.L. Ustin. 2003. Mapping non-native species using hyperspectral imagery. 2003. Remote Sensing of Environment 86(2):150-161.

Ustin, S.L., D.A. Roberts, J.A. Gamon, and G.P. Asner, 2004. Using Imaging Spectroscopy to Study Ecosystem Processes and Properties. Bioscience 54:523-534.

Ustin, S.L. (volume editor) 2004. Manual of Remote Sensing Vol. 4. Remote Sensing for Natural Resource Management and Environmental Monitoring.ASPRS. John Wiley and Sons, New York. 768p. +cd.

Ustin, S.L., S. Jacquemoud, P. Zarco-Tejada, and G. Asner. 2004. Remote Sensing of Environmental Processes: State of the Science and New Directions. In: Manual of Remote Sensing Vol. 4. Remote Sensing of Natural Resource Management and Environmental Monitoring (S.L. Ustin, vol. ed.). ASPRS. John Wiley and Sons, New York, pages 679-730.

Zarco-Tejada, P.J., Rueda, C.A., and Ustin, S.L. 2003. Water content estimation in vegetation with MODIS reflectance data and model inversion methods. Rem. Sen. Envir. 85:109-124.

Zarco-Tejada, P.J., Pushnik, J.C., Dobrowski, S., and Ustin, S.L. 2003. Steady-state Chlorophyll Fluorescence detection from Canopy Derivative reflectance and *Double-Peak* effects**.** Remote Sensing of Environment 84(2):283-294.

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Education

M.S., M.Phil, Ph.D. Biometeorology, Yale University, New Haven, CT, 1976,1977,1980; Massachusetts Institute of Technology, B.S. Earth and Planetary Sciences, 1975

Professional Experience

1984-present Assistant, Associate and Full Professor of Atmospheric Science and Biometeorologist in the Experiment Station, University of California, Davis.

2001-2004 Vice Chair for Atmospheric Science, Department of Land, Air and Water Resources, University of California, Davis.

1998 (July, August) Chercheur, Unite de bioclimatologie, INRA, Bordeaux, France

1997-1998 Research Scientist, Atmospheric Turbulence and Diffusion Division, National Oceanic and Atmospheric Administration, Oak Ridge, Tennessee (sabbatic leave)

1990-1991 Chercheur, Station de bioclimatologie, INRA, Thiverval-Grignon, France (1yr sabbatic leave)

1980-1984 Assistant Professor of Boundary Layer Meteorology and Biometeorology, Dept. of Agronomy, Purdue University

1977 (Summer) Meteorologist, National Oceanic and Atmospheric Administration/National Earth Satellite Service, Washington SFSS

Synergistic Activites

(1) Editor-in-Chief, *Agricultural and Forest Meteorology* (an international journal) 1998-present; Regional Editor for North America, *Agricultural and Forest Meteorology* (an international journal) 1991-1997; (2) Invited Lecturer, Advanced Short Course on Agricultural, Forest and Micrometeorology, Bologna, Italy, October 8-12, 2001 (3) Invited Lecturer & Speaker to the Chinese Academy of Meteorological Science and the Chinese National Climatic Center, Beijing, China, September, 2000 (4) Invited Lecturer, Advanced Short Course on Biometeorology and Micrometeorology, Alghero, Sardenia,Italy, June 26-July 1, 1995, sponsored by the University of Sassari, Italy.(5) Outreach to Birch Lane Elementary School, Davis, CA through the GLOBE program; undergraduate class visits to this school to supervise atmospheric science activities grades 4-6; calibration of the GLOBE weather station on site.

Collaborators and Other Affiliates

(i) Collaborators: P. Anthoni, Oregon St. U., D. Baldocchi, UC Berkeley, C. Bernhofer, Technische U. Dresden, R. Bi, Michigan T. U., B. J. Bond, Oregon St. U., K. D. Brosofske, U. Rhode Island, Chen, J, U. Toledo; Ken Davis, Penn State U., P. Duce, CNR Italy, E. Euskirchen, Michigan Technological U., J. Finnigan, CSIRO Australia, E. Falge, U. Bayreuth, J. Fuentes, U. Virginia, A. Goldstein, UC Berkeley, L. Gu, Oak Ridge Nat. Lab., D. Hollinger, USDA For. Serv., G. Katul, Duke U. B. Law, Oregon St. U.,X. Lee, Yale, D. Lis, Inst. Occup. Med. Env. Health, Poland, Y. Mahli, U Edinburgh, T. Meyers, ATDD/NOAA, C.H. Moeng, NCAR, W. Munger, Havard, W. Oechel, San Diego St. U., R. Olson, Oak Ridge National Lab.,

J. Pastuszka, Inst. Occup. Med. Env. Health, Poland, N. Phillips, Boston U., K. Pilegaard, Risoe Nat. Lab., R. D. Pyles, U. Colorado, S. Running, U. Montana, R. Shaw, UCDavis, R. Snyder, UC Davis, D. Spano, U. Sassari, Italy, T. H. Suchanek, US Fish & Wildlife Service, P. Sullivan, NCAR, K. Ulfig, Inst. Ecology Indust. Areas, Poland, S. L. Ustin, UCDavis, R. Valentini, U. Tuscia, S.Verma, U. Nebraska, T. Vesala, A. Wlazlo, Inst. Occup. Med. Env. Health, Poland, U. Helsinki, B. Weare, UC Davis, K. Wilson, ATDD/NOAA, S. Wofsy, Harvard

(ii) Graduate Advisors: W. Reifsnyder, emeritus, Yale University

(iii) Thesis advisees in past five years (9):

M.Falk (UCDavis & UCBerkeley),L. Fitzmaurice (UCDavis), E.M. Gonzalez (UCDavis), A.J. Ideris (UCDavis), J. Kochendorfer (UCDavis), Y-S.Park (UCDavis), S. Wharton (UCDavis), B. Yang (UCDavis), L. Xu (UCDavis)

Publications - *Five Publications Related to Present Project:*

Paw U, K.T., M. Falk, T.H. Suchanek, S.L. Ustin, Y-S. Park, W.E. Winner, S.C. Thomas, T.C. Hsiao, R.H. Shaw, T.S. King, R.D. Pyles, M. Schroeder. 2004. Carbon Dioxide exchange between and old-growth forest and the atmosphere. Ecosystems 7:513-524.

Pyles, R.D., B.C. Weare, K.T.Paw U, W. Gustafson. 2003. Coupling between the University of California, Davis, Advanced Canopy-Atmopshere-Soil Algorithm (ACASA) and MM5: Preliminary Results for July 1998 for Western North America. J. Appl. Meteorol. 42:557-569.

Paw U, K.T., D.D. Baldocchi, T.P. Meyers, and K. Wilson. 2000. Correction of eddy-covariance measurements incorporating both advective effects and density fluxes. Boundary-layer Meteorol. 97:487-511.

Pyles, R.D., B.C. Weare, and K.T. Paw U. 2000. The UCD advanced-canopy-atmosphere-soil algorithm (ACASA): Comparisons with observations from different climate and vegetation regimes. Quart. J. Roy. Meteorol. Soc. 126:2951-2980.

Paw U, K.T., J. Qiu, H.B. Su, T. Watanabe, and Y. Brunet. 1995. Surface renewal analysis: a new method to obtain scalar fluxes without velocity data. Agric. For. Meteorol. 74:119-137.

Other Publications

Law, B.E., E. Falge, L. Gu, D.D. Baldocchi, P. Bakwin, P. Berbigier, K. Davis, A.J. Dolman, M. Falk, J.D. Fuentes, A.H. Goldstein, A. Grelle, A. Granier, D. Hollinger, I.A. Jansen, P. Jarvis, N.O. Jensen, G. Katul, Y. Malhi, G. Matteucci, T. Meyers, R. Monson, J.W. Munger, W. Oechel, R. Olson, K. Pilegaard, K.T. Paw U, Thorgeirsson , R. Valentini, S. Verma, T. Vesala, K. Wilson, and S. Wofsy. 2002. Environmental Controls over Carbon Dioxide and Water Vapor Exchange of Terrestrial Vegetation. Agric. For. Meteorol. Agric. For. Meteorol.113:97-120. (Winner of the 2004 Norbert-Gerbier Award from the World Meteorological Organization)

Su, H.-B., R.H. Shawand, K.T. Paw U. 2000. Two-point correlation analysis of neutrally stratified flow within and above a forest from large-eddy simulation. Boundary-layer Meteorol. 94:423-460.

Su, H.-B., R.H. Shaw K.T. Paw U, C-H. Moeng, and P.P. Sullivan. 1998. Turbulent statistics of neutrally stratified flow within and above a sparse forest from large-eddy simulation and field observations. Boundary-layer Meteorol. 88:363-397.

Paw U, K.T. and L.T. Meyers, 1989. Investigations with a higher-order canopy turbulence model into mean source-sink levels and bulk canopy resistances. Agric. For. Meteorol. 47:259-272.

Gao, W., R.H. Shaw and K.T. Paw U. 1989. Observations of organized structure in turbulent flow within and above a forest canopy. Boundary-Layer Meteorol. 47:349-377.

CURRICULUM VITAE

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Education

National Taiwan University, Taipei, Taiwan , Atmospheric Sciences, B.S., 1993; Purdue University, West Lafayette, IN, Atmospheric Sciences, M.S., 1995; Purdue University, West Lafayette, IN, Atmospheric Sciences, Ph.D., 1999

National Center for Atmospheric Research, Boulder, CO, Mesoscale modeling and data assimilation, Postdoctoral Associate(12/99 ~ 09/01)

Professional Experience

Assistant Professor of Mesoscale Meteorology, Department of Land, Air & Water Resources, University of California, Davis. 09/01- present

Synergistic Activities

Involved in the development of the Weather Research and Forecast (WRF) model, designing the interface for each physics component, connecting the prognostic variable tendencies between the dynamics and physics, and implementing several physics schemes, 12/99 – present

Invited participant to: Third US-Korea Joint Workshop on Weather Analysis and Prediction, 02/02

Collaborators & Other Affiliations

Ph.D. Advisor: Prof. Wen-Yih Sun, Purdue University, IN
Post-doctoral Advisor: Chris Davis, National Center for Atmospheric Research, CO
Collaborators since 1995:
Prof. Yuh-Lang Lin, North Carolina State University
Prof. Song-You Hong, Yonsei University, Seoul, Korea
Dr. Jimy Dudhia, National Center for Atmospheric Research
Dr. Francois Vandenberghe, National Center for Atmospheric Research
Grant W. Petty, University of Wisconsin
James F. Bresch, National Center for Atmospheric Research
Hsiao-ming Hsu, National Center for Atmospheric Research

Supervised Ph.D. Students

Bruce McDowell
Zhan Zhao
Elcin Tan

Publications

Most Relevant to Current Proposal

Chen, S.-H., F. Vandenberghe, G. W. Petty, and J. F. Bresch, 2004: Application of SSM/I satellite data to a hurricane simulation, Quart. J. Roy. Meteor. Soc., 130, 801-825.

Huang, C.-Y., Y.-H. Kuo, S.-H. Chen, and F. Vandenberghe, 2004: Improvements on typhoon forecast with assimilated GPS occultation refractivity. Weather and Forecasting, under revision.

Other Publications

Chen, S.-H. and Y.-L. Lin, 2004: Orographic effects on a conditionally unstable flow over an idealized three-dimensional mesoscale mountain, Meteor. Atmos. Phys., in press.

Chen, S.-H, and W.-Y. Sun, 2004: An explicit one-dimensional time-dependent tilting cloud model, submitted to J. Atmos. Sci, in press.

Chen, S.-H. and Y.-L. Lin, 2004: Effects of Moist Froude Number and CAPE on a Conditionally Unstable Flow over a Mesoscale Mountain. Submitted to J. Atmos. Sci, in press.

Hong, S.-Y., J. Dudhia, and S.-H. Chen, 2004: A Revised Approach to Ice Microphysical Processes for the Bulk Parameterization of Clouds and Precipitation, Mon. Wea. Rev., 132:103-120.

Chen, S.-H., and W.-Y. Sun, 2002: A one-dimensional time-dependent cloud model. J. Meteor. Soc. Japan 80:99-118.

Chen, S.-H., and W.-Y. Sun, 2001: The applications of the Multigrid method and a flexible hybrid coordinate in a nonhydrostatic model. Mon. Wea. Rev. 129:2660-2676.

CURRICULUM VITAE
David R. Smart

Assistant Professor of Viticulture and Enology
Dept. of Viticulture & Enology
UC Davis, Davis, CA 95616
Tel. (530) 754-7143; Fax (530) 752-0382; E-mail: drsmart@ucdavis.edu

Education
University of California at Davis, Ph.D. Botany, 1990

Professional Experience
2000-present Assistant Professor, Dept. Viticulture & Enology, Univ of Calif., Davis
1997 – 2000 Visiting Scientist, Dept. Vegetable Crops, Univ. of Calif., Davis
1994 – 1997 Research Scientist, Dept. Ecol. & Forestry, Univ. Auton. de Barcelona
1991 – 1994 Postdoctoral Fellow, Dept. Plants, Soils Biometeorology, Utah State Univ.

Research Interests
Viticulture, precision viticulture, root physiological ecology, influence of deficit irrigation on root demographics, leaf exchanges of nitrogen trace gases, environmental and biotic controls on trace gas emissions from the plant soil system. Environmental and biotic controls on carbon trace gas emissions from the plant soil system.

Relevant Publications
Smart, D.R, E. Carlisle and B. Alonso. 2004. Transverse hydraulic redistribution by a grapevine (*V. rupestris* X *V. berlandieri* cv 420A). Plant, Cell & Environ. (in press)

Volder, A., D.R. Smart, A.J. Bloom and D.M. Eissenstat. 2004. Rapid decline in nitrate uptake and respiration with age in fine lateral roots of grape: Implications for root efficiency and competitive effectiveness. New Phytologist (in press).

Smart, D.R. and J. Peñuelas. 2004. Changes in soil CO_2 respiration following precipitation onto dry soils: An investigation of elevated CO_2 using Mediterranean plants. Applied Soil Ecology (in press)

Smart, D.R. 2004. Exposure to elevated carbon dioxide concentration in the dark lowers the respiration quotient of *Vitis* cane wood. Tree Physiology 24:115-120.

Stark, J.M., D.R. Smart, K. Haubensak and S.C. Hart. 2002 Regulation of nitric oxide emissions from forest and rangeland soils of Western North America, Ecology 83:2278-2292.

Bloom, A.J., D.R. Smart, P. Searles and D. Nguyen 2001 Elevated carbon dioxide concentrations inhibit nitrate assimilation in wheat shoots. Proceedings of the National Academy of Sciences of the United States of America 99: 1730-1735

Smart, D.R. and A.J. Bloom. 2001. Leaves emit nitrous oxide during nitrate assimilation. Proceedings of the National Academy of Sciences of the United States of America, 98:7875-7878.

Smart, D.R., J. Stark and V. Diego, 1999. Resource limitations on nitrogen trace gas emissions from a sage-steppe ecosystem. Biogeochemistry 47:63-86.

Smart, D.R., K. Ritchie, A.J. Bloom, B.B. Bugbee. 1998. Nitrogen and water balances for wheat canopies (*Triticum aestivum* cv. Veery 10) grown under elevated and ambient CO_2 concentrations. Plant Cell & Environ. 21:753-764.

Smart, D.R., K. Ritchie, J. Stark, and B. Bugbee. 1997. Evidence that elevated CO_2 increases rhizosphere denitrifier activity. Applied and Environmental Microbiology 63:4621-4624.

CURRICULUM VITAE
Judith Z. Drexler

U.S. Geological Survey
6000 J Street, Placer Hall
Sacramento, CA 95819-6129
Tel.: (916) 278-3057; Fax: (916) 278-3071; E-mail: jdrexler@usgs.gov

Education

Cornell University, Ithaca, New York, Ph.D. Natural Resources, 1996; University of Colorado, Boulder, Colorado, M.A. Physical Geography, 1991; University of California, Berkeley, California, B.A. Environmental Science, 1985

Major Research Interest

(1) Wetland restoration as a tool for mitigating land-surface subsidence
(2) Historic peat accretion in the Sacramento-San Joaquin Delta
(3) Influence of evapotranspiration and groundwater on wetland structure and function
(4) Impacts of nutrient loading, invasive species, and pollutants on wetland sustainability

Professional Experience

2000-present - Wetland Ecologist, U.S. Geological Survey, Sacramento, California. My current research program consists of the following self-funded projects: (1) a field- and lab-based research project determining the rates and controls on historic peat accretion in the Sacramento-San Joaquin Delta; and (2) the determination of elevation ranges for SF Bay salt marsh vegetation through analysis of vegetation surveys done by the Survey and the California State Lands Commission. I collaborate with one scientist and supervise one technician for these projects.

2000-present - Scientist, Delaware Department of Transportation, Dover, Delaware. Team leader in charge of conducting ecological assessments of created wetlands during summer 2000 throughout the state of Delaware. Conducted point quarter sampling of vegetation, soil sampling, planting of various perennial species, and statistical analyses of vegetation characteristics.

1999-2000 - Part-time Postdoctoral Researcher, University of Delaware, School of Marine Studies, Lewes, Delaware. Analyzed and ground-truthed thermal imagery taken to detect groundwater discharge areas along the coastline of the Delaware Bay. Ran experiment on the influence of marine polychaete worms on the hydraulic conductivity of sand.

1997-1999 - Postdoctoral Research Hydrologist, USDA Forest Service, Institute of Pacific Islands Forestry, Honolulu, Hawaii. Designed and carried out a study on the hydro-chemical and ecological linkages between freshwater swamps and mangrove ecosystems on the islands of Pohnpei and Kosrae, Federated States of Micronesia. Competed successfully for Forest Service grant to expand research. Supervised two technicians during fieldwork. Managed budgets, analyzed data, and produced manuscripts from research.

1996 Instructor: The Central European University, Budapest, Hungary. Gave lectures in graduate ecology course, graded assignments and exams, and assisted in running the Master's program in the Department of Environmental Science and Policy.

Professional Affiliations
Ecological Society of America
Society of Wetland Scientists
Society of Wetland Scientists Western Chapter - Treasurer
Estuarine Research Federation

Peer-review Articles

Drexler, J.Z., R.L. Snyder, D. Spano, and K.T. Paw U. 2004. A review of models and methods to estimate wetland evapotranspiration. Hydrological Processes 18(11): 2071-2101.

Anderson, F.E., R.L. Snyder, R.L. Miller, and J.Z. Drexler. 2003. A micrometeorological investigation of a restored California wetland ecosystem. Bulletin of the American Meteorological Society, September 2003.

Drexler, J.Z. and B.L. Bedford. 2002. Pathways of Nutrient Loading and Impacts on Plant Diversity in a New York Peatland. Wetlands 22(2):263-281.

Drexler, J.Z. and E. De Carlo. 2002. Source water partitioning as a mean of characterizing hydrologic function of mangroves. Wetlands Ecology and Management 10(2):103-113.

Drexler, J.Z. and K.C. Ewel. 2001. Effects of ENSO-related drought on hydrology and salinity in a Micronesian wetland complex. Estuaries 24(3):347-356.

Drexler, J.Z. 2001. Maximum longevities of *Rhizophora apiculata* and *R. mucronata* propagules. Pacific Science 55(1):17-22.

Drexler, J.Z., B.L. Bedford, R. Scognamiglio, and D.I. Siegel. 1999. Fine-scale characteristics of groundwater flow in a peatland. Hydrological Processes 13:1341-1359.

Drexler, J.Z., B.L. Bedford, A. DeGaetano, and D.I. Siegel. 1999. Quantification of the water budget and nutrient loading for a small peatland in central New York. Journal of the American Water Resources Association 34(4):753-769.

Recent Contributed Papers and Published Abstracts

Fujii, R., J.A. Fleck, G. Wheeler, and J.Z. Drexler. Assessment of water quality in a restored, non-tidal wetland in the Sacramento- San Joaquin Delta: focus on DOC and disinfection byproduct precursors. State of the Estuary Conference, Oakland, California, 2003.

Drexler, J.Z., J. Fleck, G. Wheeler, and R. Fujii. Carbon storage and sediment accretion in restored wetlands on Twitchell Island. CALFED Science Conference 2003, Sacramento, California, January 2003.

Anderson, F.E., R.L. Snyder, K.T. Paw U, and J.Z. Drexler. An energy budget evaluation of a restored California Delta ecosystem using the eddy covariance method in comparison with the surface renewal method. American Meteorological Society, 15th Conference on Biometeorology and Aerobiology, Kansas City, Missouri, October 2002.

Drexler, J.Z. and R.L. Snyder. 2002. Review of the canopy coefficient method for determining wetland evapotranspiration. Society of Wetland Scientists Western Chapter Conference, Tiburon, California, September 2002.

Drexler, J.Z., G. Wheeler, and R. Fujii. Wetland restoration as a means for mitigating land-surface subsidence, Sacramento-San Joaquin Delta, California. Ecological Society of America and Society for Ecological Restoration Joint Conference, Tucson, Arizona, August 2002.

CURRICULUM VITAE
Neil O'Connell

Cooperative Extension
University of California
One Shields Ave.
Davis, CA 95616

Education
Arizona State University, B.S. Entomology; University of Arizona, M.S. Entomology

Employment
1981-present Farm advisor, University of California, Cooperative Extension-Tulare County.
Responsibilities include: Education Program Development and delivery of a researched-based information program and
Research Program: Conduct applied research addressing significant issues to the industry
Crop Responsibilities: Citrus and Olives

Publications
Grafton-Cardwell, E.E., N.V. O'Connell, C.E. Kallsen and J.G. Morse. 2003. Photographic Guide to Citrus Fruit Scarring. UC publication 8090.

Liu, F. and N.V. O'Connell. 2003. Movement of Simazine in Water and Weed Control from a Citrus Orchard as Affected by Reduced Rate of Herbicide Application. Bioresources Technology 86:253-258.

Liu, F. and N.V. O'Connell. 2003. Simazine Runoff from Citrus Orchards Affected by Shallow Mechanical Incorporation. Journal of Environmental Quality 32(1):78-83.

Cardwell,E.G., J.G. Millar, N.V. O'Connell, and L.M. Hanks. 2000. Sex Pheromone of yellow scale, Aonidiella citrina(*Homoptera:Diaspididae*): Evaluation as an IPM tatic.J.Agric.Urban Entomol. 17(2):75-88.

O'Connell, N.V., R.L. Synder. 1999. Cover crops, mulch lower night temperatures in citrus. California Agriculture 53(5):37-40.

CURRICULUM VITA
Harry L. Carlson

Superintendent/Farm Advisor
University of California
Intermountain Research & Extension Center
P.O. Box 850, Tulelake, California 96134

Education
University of California, Davis, Ph.D. Ecology, 1985; University of California, Davis, M.S. Agronomy, 1981; University of California, Davis, B.S. Wildlife Biology, 1970.

Research Interest
Evaluation and development of new potato cultivars and markets; Integrated pest management: weeds, insects, nematodes, and diseases; Integrated crop management: varieties, fertilizer and irrigation; Monitoring and ameliorating effects of agricultural production on environmental quality; Experimental design and conduct of field research experiments.

Professional Experience
1998 – Present Superintendent/Farm Advisor, University of California Intermountain Research Extension Center, Tulelake, California. Administer 120-acre field research center; direct research, manage personnel, budget and facilities. Conduct an active education and applied research program in field and vegetable crops. Provide crop cultural advise to growers farming 120,000 acres in Modoc and Siskiyou counties.

1995 - 1997 Director, Research and Extension Centers (REC), University of California. Responsible for leadership and administration of the University's system of 10 Research and Extension Centers located in major agricultural areas throughout the state. Supervised 10 academic Center Superintendents and guided a combined annual operations and capitol improvement budget of more than $9,000,000. Each year the system supported more than 350 individual field, laboratory, or greenhouse research projects; conducted by approximately 170 research project leaders.

1984 – 1994 Superintendent/Farm Advisor, University of California Intermountain Research Extension Center, Tulelake, California.

1981 – 1983 Farm Advisor and Research Assistant, Agronomy Department, University of California. Conducted field and vegetable crops research and education programs in Modoc and Siskiyou counties. Conducted detailed research on weed-crop interaction.

1975 - 1981 Staff Research Associate, Agronomy and Botany Departments, University of California, Davis. Conducted statewide evaluations of small grain varieties. Conducted herbicide and weed competition studies in tomatoes, dry beans, winter cereals, and landscape ornamentals.

Professional Affliations
American Society of Agronomy, Potato Association of America, Soil Science of America, Crop Science Society of America, Research Center Administrators Society

Peer-Review Publications

Carlson, H.L. and R. Todd. 2002. Effects of the 2001 Water Allocation Decisions on the Agricultural Landscape and Crop Production in the Klamath Reclamation Project. p. 163-176. In: Water Allocation in the Klamath Reclamation Project, An Assessment of Natural Resource, Economic, Social and Institutional Issues. Special Report 1037. Oregon State University, Corvallis, Oregon.

Carlson, H.L., D.R. Clark, K. Locke, and R. Todd. 2002. Soil Resources in the Klamath Reclamation Project. p. 153-161. In: Water Allocation in the Klamath Reclamation Project, An Assessment of Natural Resource, Economic, Ssocial and Institutional Issues. Special Report 1037. Oregon State University, Corvallis, Oregon.

Mateos, L., C.A. Young, W.W. Wallender and H.L. Carlson. 2000. Simulating Spacially Distributed Water and Salt Balances. Journal of Irrigation and Drainage Engineering. 126(5):288-295.

Drake, D.J., K.W. Tate, H.L. Carlson. 2000. Analysis Shows Climate Caused Decrease in Scott River Fall Flows. California Agriculture 54(6):46-49.

Voss, R., H. Phillips, K. Brittan, H.L. Carlson, et.al. 1999. New Specialty Potato Varieties Give Farmers Growing and Marketing Options. California Agriculture 3(6):16-20.

Attachment 7. Table C-5: Project Annual Physical Benefits (Quantitative and Qualitative Description of Benefits)

QUALITATIVE DESCRIPTION - REQUIRED OF ALL APPLICANTS[1]				QUANTITATIVE BENEFITS –(where data are available) [2]
Description of physical benefits (in-stream flow and timing, water quantity and water quality) for:	**Time Pattern and Location of Benefit**	**Project Life: Duration of Benefits**	**State Why Project Bay-Delta benefit is Direct[3], Indirect[4] or Both**	**Quantified Benefits (in-stream flow and timing, water quantity and water quality)**
Bay-Delta: .The physical benefits (in-stream flow and timing, water quantity and water quality) could be greatly enhanced by the CIMIS II project. However, the actual benefits depend on grower adoption and use of the improve ET information.	Since the CIMIS II project would provide ET information year round, there is no specific time pattern effect. However, in-stream flow will be more manageable with the CIMIS II project.	The project life is 3 years but the benefits will accrue over a much longer time.	Direct benefits will occur over the long term as more growers adopt and use the improved ET delivery system. CIMIS II will also build a framework for more work on regulated deficit irrigation that could further lead to efficient water use.	It is not possible to estimate the effects of CIMIS II on in-stream flow and timing, water quantity and water quality). It ultimately depends on grower adoption. However, with CIMIS II, grower adoption is more likely to occur than with any other conceivable project. The limiting factor to grower adoption of ET-based scheduling is the complexity of estimating ETc from ETo. This will be eliminated by CIMIS II. Therefore, the benefits should be considerable.
Local: The local physical benefits should be realized in more efficient water management. The project will document water use for environmental enhancement throughout the State.	Local benefits will be statewide and in all seasons.	Local benefits will likely accrue as growers adopt and use the system.	**Not Applicable**	At the field level, CIMIS II will increase water use efficiency. The amount of water savings depends on grower adoption, which should increase. It is likely to be at least as effective at improving water savings as the original CIMIS project.

[1]The qualitative benefits should be provided in a narrative description. Use additional sheets to describe the benefits.
[2] The project benefits that can be quantified (i.e. volume of water saved or mass of constituents reduced) should be provided.
[3] Direct benefits are project outcomes that contribute to a CALFED objective within the Bay-Delta system during the life of the project.
[4]Indirect benefits are project outcomes that help to reduce dependency on the Bay-Delta system. Indirect benefits may be realized over time.
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