ACCURACY OF EVAPORATION AND ET MODELS FOR TAHOE NOW AND IN THE FUTURE

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Introduction – Open Water Evaporation

- Open water evaporation is one of the most difficult surface energy fluxes to quantify and is rarely directly measured in the natural environment

- Reservoir operations and the development of new storage and water accounting strategies require estimates of evaporation and net evaporation (E minus PPT)

- Projected changes in open water evaporation under future climate scenarios are uncertain, but is probably going to go up simply due to warming surface temperatures

Introduction – Open Water Evaporation

- Primary factors that govern open water evaporation include
  - net radiation
  - heat storage
  - air temperature
  - water surface “skin” temperature
  - humidity
  - wind speed
  - stability of the atmosphere
  - advection of water and heat in and out of the water body
  - salinity
- Aerodynamics of the water surface, turbidity of the water, and inflow and outflow rates control the rate of transfer between energy balance variables.
- All of these factors are important to consider when deciding which technique is most appropriate given the application and data requirements

Introduction – Open Water Evaporation

- Common indirect techniques include
  - pan evaporation and pan coefficients
  - water budget
  - energy budget
  - mass transfer
  - combination of energy and mass transfer techniques

- The eddy covariance technique is a direct approach, and considered the most accurate if environmental conditions, physical setting of the water body of interest, and experimental design is ideal
  - Eddy Covariance, EC (Enough Corrections!!)
  - Hard to collect data on shore due to fetch issues
  - Hard to collect data over water with a float due moving horizontal plane
  - Subject to energy imbalance blues…

- The water budget technique is considered the most accurate indirect approach in arid environments where in gaged inflows are minimal and evaporation is a relatively large component of the water budget

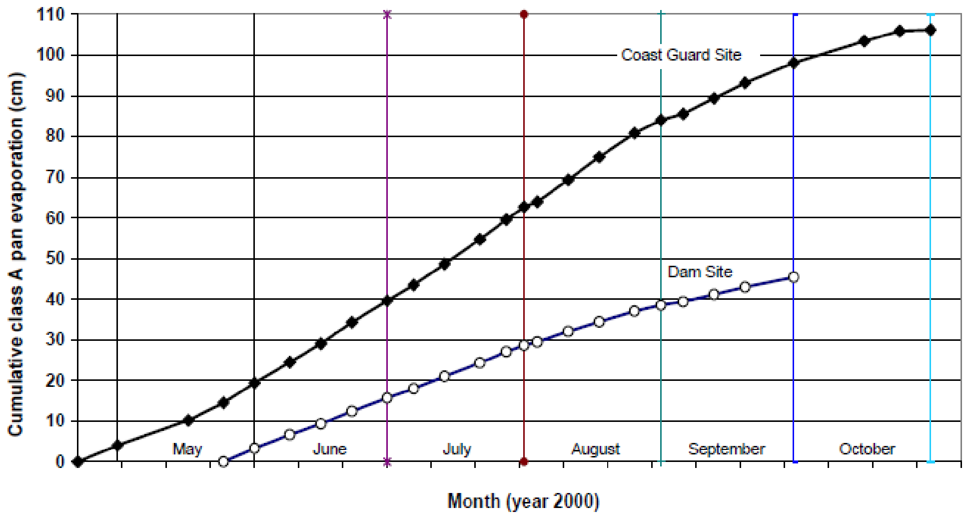
Pan Evaporation

- Historically, evaporation from Lake Tahoe for operations has been estimated using average pan evaporation information
- Pan data are widely known to have significant uncertainty both in magnitude and timing
- Evaporation pans can over estimate lake or reservoir evaporation by 25 to 100% when compared to water or energy balance estimates of evaporation
- Freezing conditions limit use of the pans
- No heat storage in a pan
- Often poorly sited and maintained

Pan Evaporation Estimates for Tahoe

- **3.23 ft/yr** (2000); Trask 2007
  - Used new Coast Guard Station site and pan coefficient of 0.71

a)



Figures from Trask (2007)

Tahoe City Dam (facing northeast across inlet to dam)

Coast Guard Station (facing south to southern end of Lake Tahoe)

Figure C1b. Class A evaporation pans at Lake Tahoe shoreline (locations shown figure C1a). Photographs from summer 1999.

Water Balance Evaporation Estimates for Tahoe

- **3.58 ft/yr** (1960-70); Dugan and McGauhey
  - Dugan, G.L. and McGauhey, P.H. (1974). Enrichment of Surface Waters. Journal WPCF, 46(10).
- **3.62 ft/yr** (1967-70); Myrup et al. (1979)
  - Myrup, L.O., Powell, T.M., Godden, D.A., and Goldman, C.R. (1979). Climatological Estimate of the Average Monthly Energy and Water Budgets of Lake Tahoe, California-Nevada. Water Resources Research, 15(6).
- **3.00 ft/yr** (1968-2000); Trask (2007)
  - Trask, J.C. (2007). Resolving Hydrologic Water Balances through Novel Error Analysis with Focus on Inter-annual and long-term Variability in the Tahoe Basin. University of California, Davis, Ph.D. Dissertation. 378 p.

Energy Balance Evaporation Estimates for Tahoe

- Most widely used in research, and is the most data intensive and complex approach due the need to consider the entire water body as a control volume rather than just the surface in the case of a land surface energy balance

- **2.94 ft/yr** (1968-70); Myrup et al. (1979) & Trask (2007)

    - Trask used energy budget estimate of sensible heat, and water budget estimate evaporation by Myrup et al. (1979) to estimate energy budget evaporation by estimating the Bowen ratio using estimated temperature and humidity gradients over the water

$E = H_{(water\ budget)} * \beta$

$$\beta = \frac{H}{LE} \approx \frac{\gamma(T_s - T_a)}{e_s^* - e_a}$$

$H_{(water\ budget)} = Rn - G - LE_{(water\ budget)}$

Aerodynamic / Bulk Mass Transfer

- Function of surface temperature, humidity, wind speed, atmospheric stability, surface roughness, thermally induced turbulence, barometric pressure, and the density and viscosity of the air

- **3.00 ft/yr** (1994-2008) – STD = 0.37ft; Sahoo et al. (2013)
  - Used weather station data (wind, RH) near Tahoe City SNOTEL and measured water surface temperature
    - Sahoo, G. B., Schladow, S. G., & Reuter, J. E. (2013). Hydrologic budget and dynamics of a large oligotrophic lake related to hydro-meteorological inputs. *Journal of Hydrology*, *500*, 127-143.

- **3.25 ft/yr** (2004); Huntington and McEvoy (2011)
  - Used NASA buoy skin temperature (e_s), humidity(e_a), and windspeed
  - Sahoo et al. (2013) estimated 2004 evaporation to be 3.47 ft using …so not that bad considering different data sources (shore vs. water)
    - Huntington, J.L. and D. McEvoy. (2011). Climatological Estimates of Open Water Evaporation from Selected Truckee and Carson River Basin Water Bodies, California and Nevada.Desert Research Institute Publication No. 41254.

Combination Approaches

- Combination energy-aerodynamic mass transfer methods are commonly used for land applications and are typically based on Penman (1948; 1956) and Penman-Monteith formulations
- **3.00 ft/yr** (+/- 0.35 ft/yr) (1968-2000) ; Trask (2007)
  - Combination of pan, aerodynamic, and energy budget approaches
- **3.61 ft/yr** (2000-2010); Huntington and McEvoy (2011)
  - Applied a energy-aerodynamic model, the Complementary Relationship Lake Evaporation (CRLE) model
  - Used UC Davis measured solar radiation, humidity, and temperature at the Tahoe City Coast Guard Pier
  - 3.23 ft/yr (2000-2008); Sahoo et al. (2013) Water Budget estimates

Summary Provided by Trask (2007)

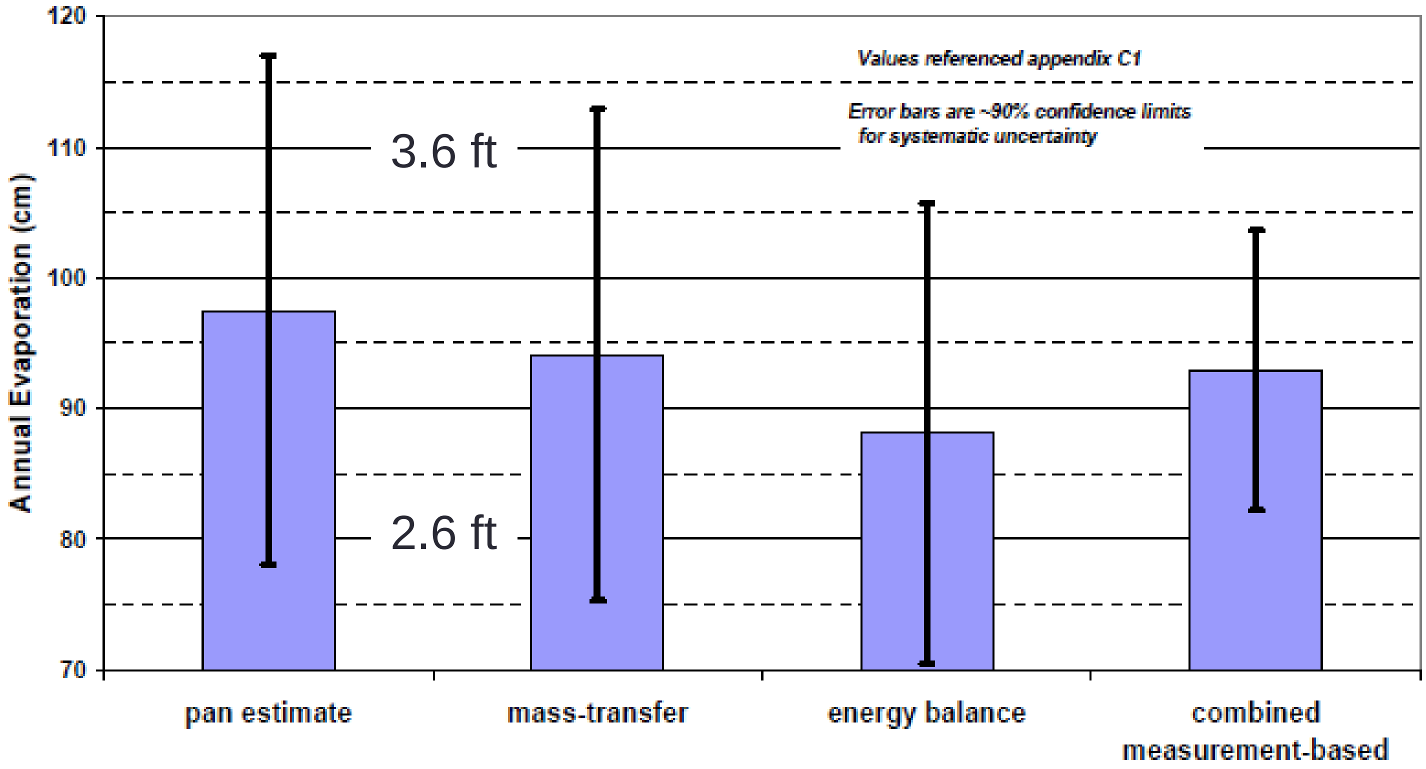


Figure C6. Measurement-based estimates performed in this dissertation of WY 1968-2000 mean annual Lake Tahoe evaporation. Shows that different methods for estimating annual mean evaporation yield comparable results. Results for independent measurement-based estimates are put together to form a 'combined' estimate (see text), which has smaller associated systematic uncertainty than any of the three individual measurement-based estimates.

Figure from Trask (2007)

Seasonal and Annual Variation Evaporation

- Heat storage is significant in Lake Tahoe
- This heat storage causes a lag in evaporation compared to PET or Pan E
- Annual water budget evaporation is higher during dry years.. that's good.. Inline with meteorology and drivers of evaporation during dry years

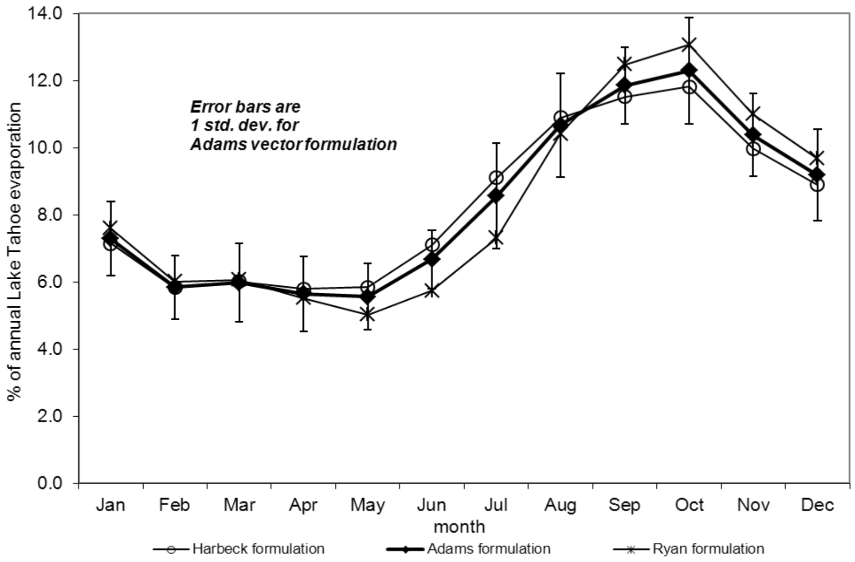
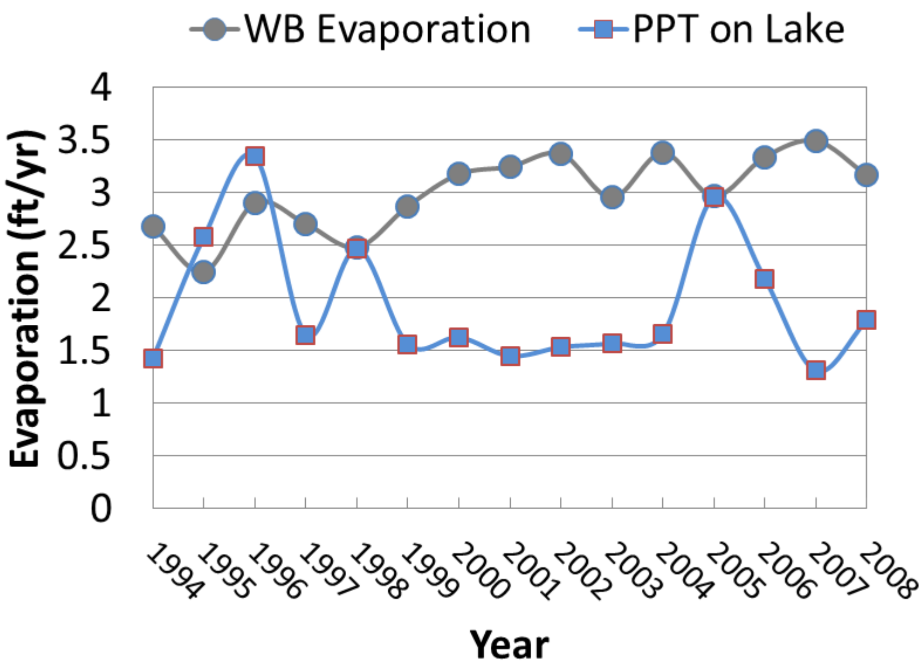


Figure from Trask (2007)

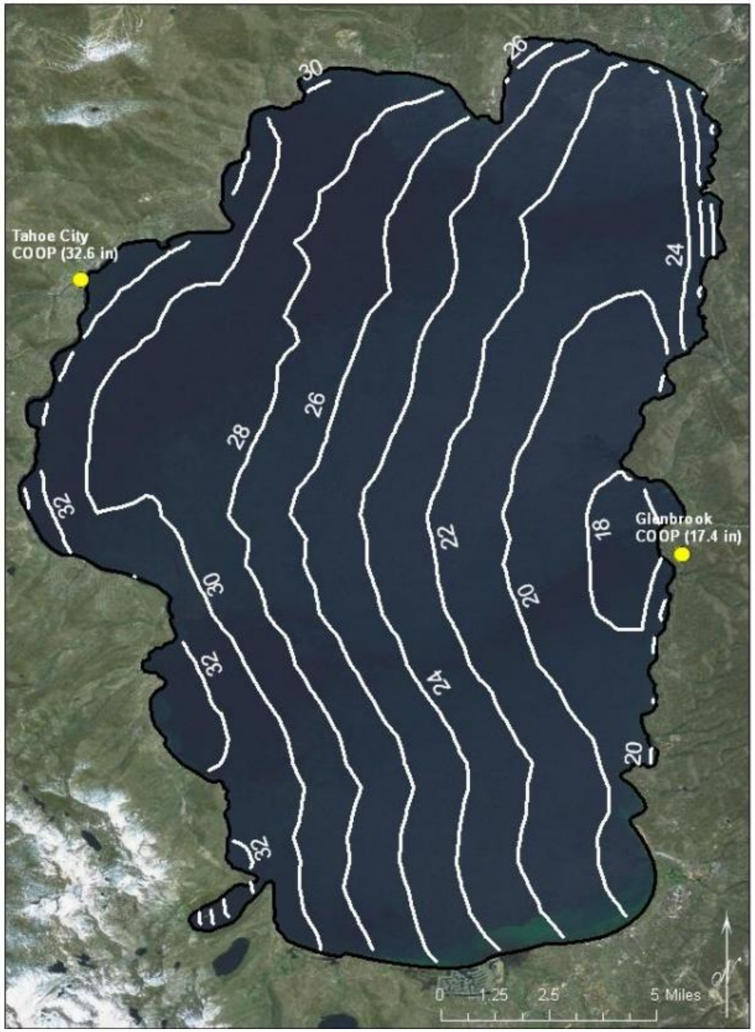


Data from Sahoo et al. (2013)

Net Evaporation; Net E = E - PPT

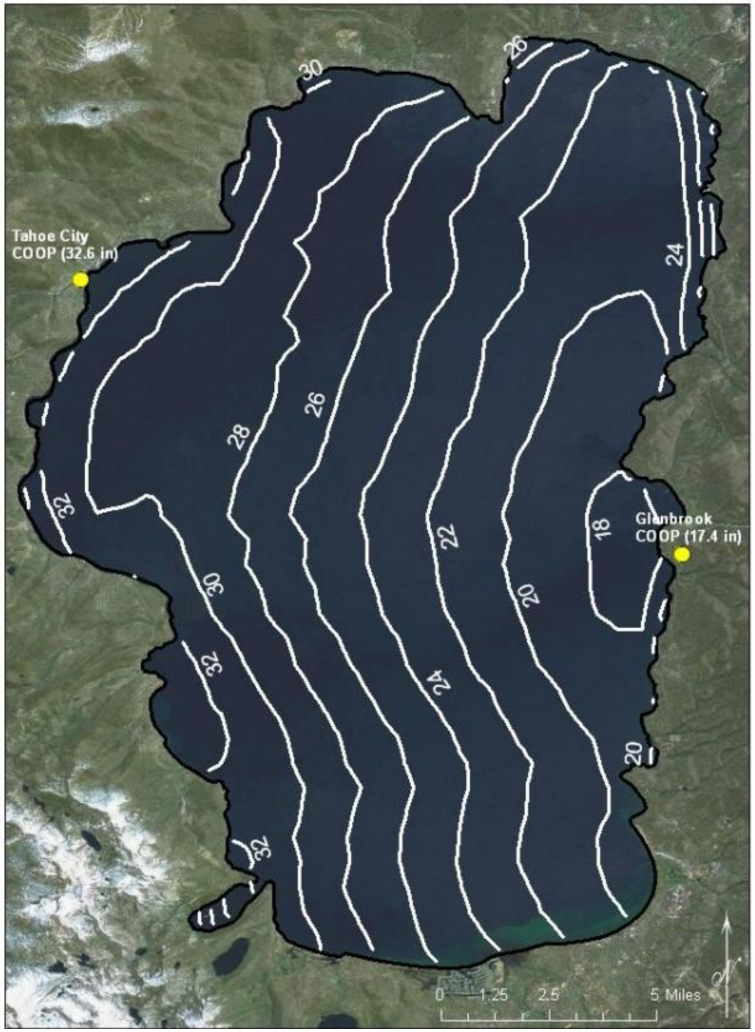
- Ultimately we need to estimate net evaporation for operations and for predicting lake stage

- Precipitation varies significantly across the lake according to the Tahoe City and Glenbrook COOP station (and PRISM.. But PRISM is just filling in the gaps...)



Net Evaporation; Net E = E - PPT

- Approach used by many to estimate precipitation across the lake:
  - Scale Tahoe City measured PPT by the ratio of spatially averaged mean monthly PRISM precipitation to mean monthly Tahoe City precipitation
  - Average scale factor is ~ 0.8



Future Projections of Evaporation

- How do we estimate evaporation in the future using a defensible approach (water budget, energy budget, aerodynamic methods)
- Water budget requires estimating all future inflows, outflows, and storage changes..
- Energy budget requires estimating lots of future variables (net radiation, heat storage, and sensible heat flux… hard ones..), and water inflows and outflows
- Aerodynamic requires future surface temperature, windspeed, and humidity

Future Projections of Lake Tahoe Evaporation

- As part of Reclamations West Wide Climate Risk assessment we used the CRLE model (Morton 1979; Morton 1983)
- Estimates monthly evaporation as a function of solar radiation, humidity, air temperature, water temperature, albedo, emissivity, and depth-controlled heat storage

VOL. 15, NO. 1 WATER RESOURCES RESEARCH FEBRUARY 1979

Climatological Estimates of Lake Evaporation

F. I. Morton

Hydrology Research Division, Environment Canada, Ottawa, Ontario K1A 0E7

A model for estimating areal evaporation and transpiration is modified slightly to provide estimates of annual lake evaporation from monthly observations of temperature, humidity, and sunshine duration (or radiation) in the land environment. The model estimates tend to be higher than the more conventional estimates in humid areas and lower in arid areas, with the latter tendency particularly noticeable in the case of Lake Nasser on the Nile River. However, the results agree very well with comparable water budget estimates for Lake Hefner in Oklahoma, the Salton Sea and Silver Lake in California, Pyramid and Winnemucca lakes in Nevada, Lake Ontario on the border between New York and Ontario, and Dauphin Lake in Manitoba. They also compare reasonably well with energy budget estimates of the evaporation from Lake Mead on the border between Arizona and Nevada when the net inflow of heat is taken into account. A technique that provides such realistic results over a wide range of depths and environments with readily available data should prove very useful in water resource or environmental impact studies. Examples of such uses are provided by maps of Canada and the southeastern United States that show average annual values of the lake evaporation, and average annual values of the difference between the evaporation from a projected reservoir, and the combined evaporation and transpiration from the area before flooding.

Introduction

There is a wide gap between the kind of information that is needed for reliable estimates of lake evaporation and the kind of information that is available for estimating the lake evaporation input to water planning and management or environmental impact studies. Thus the former requires research on the scale of the International Field Year on the Great Lakes (IFYGL), the Lake Hefner studies, or the Salton Sea investigation, whereas the latter is limited to routine pan evaporation mization of coefficients. Changes to the albedo and the emissivity terms modify the model in such a way that it can provide estimates of monthly evaporation from shallow lakes and estimates of annual evaporation from any lake.

To test this capability, the model estimates have been compared with published water balance estimates for Lake Hefner in Oklahoma, Pyramid Lake and Winnemucca Lake in Nevada, Silver Lake and the Salton Sea in California, and Lake Ontario on the border between the Province of Ontario and the State of New York. These include a wide range of depths

Journal of Hydrology, 66 (1983) 77—100 77
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

[3]

OPERATIONAL ESTIMATES OF LAKE EVAPORATION

F.I. MORTON

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(Received June 22, 1982; revised and accepted August 11, 1982)

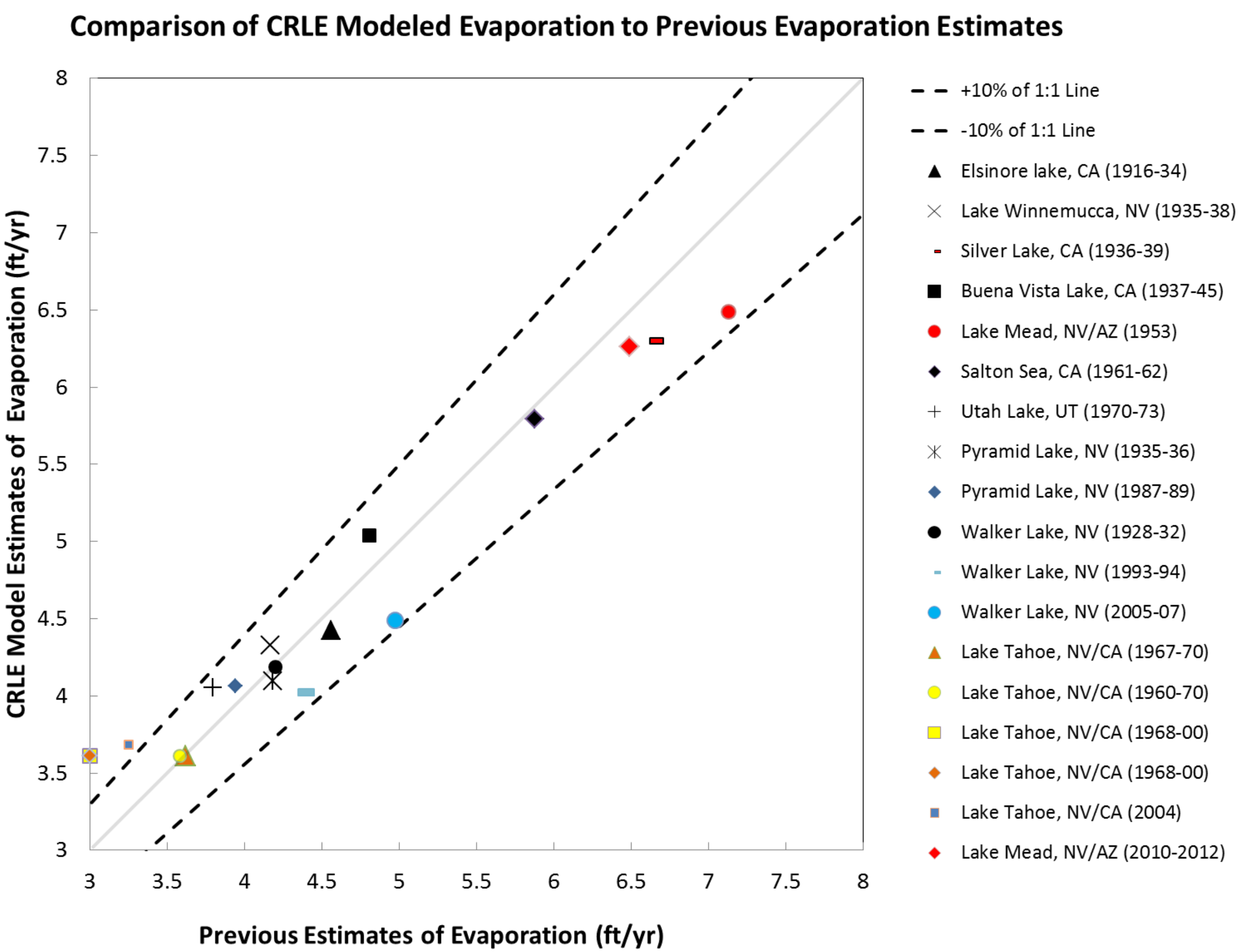
ABSTRACT

Morton, F.I., 1983. Operational estimates of lake evaporation. J. Hydrol., 66: 77—100.

The complementary relationship between areal and potential evapotranspiration takes into account the changes in the temperature and humidity of the air as it passes from a land environment to a lake environment. Minor changes convert the latest version of the complementary relationship areal evapotranspiration (CRAE) models to a complementary relationship lake evaporation (CRLE) model. The ability of the CRLE model to produce reliable estimates of annual lake evaporation from monthly values of temperature, humidity and sunshine duration (or global radiation) observed in the land environment

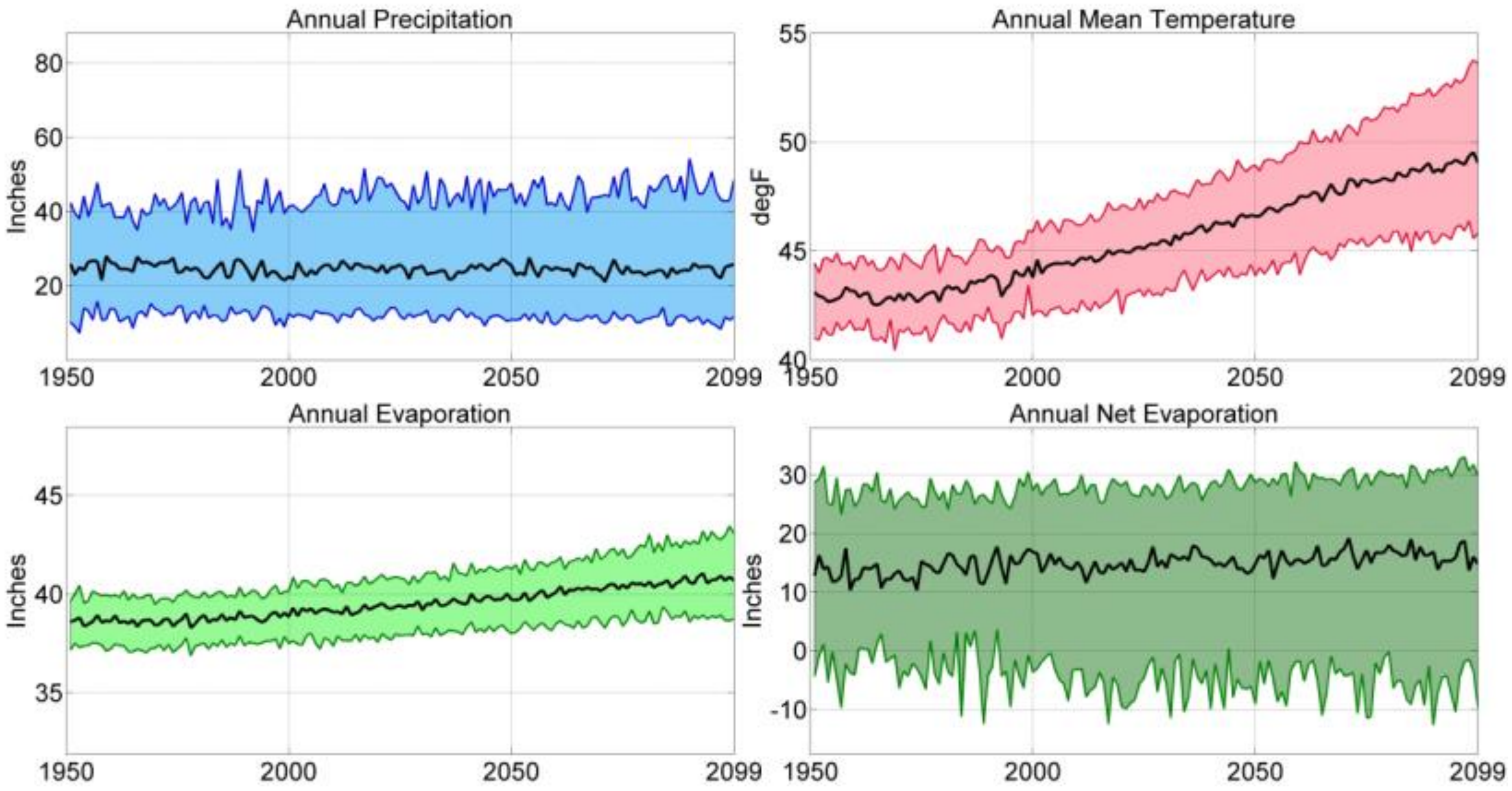
Evaluation of Historical CRLE Estimates

- CRLE method provides realistic seasonal and annual patterns of evaporation for many lakes and reservoirs and tends to account well for effects of depth and associated heat storage on the timing and magnitude of lake evaporation



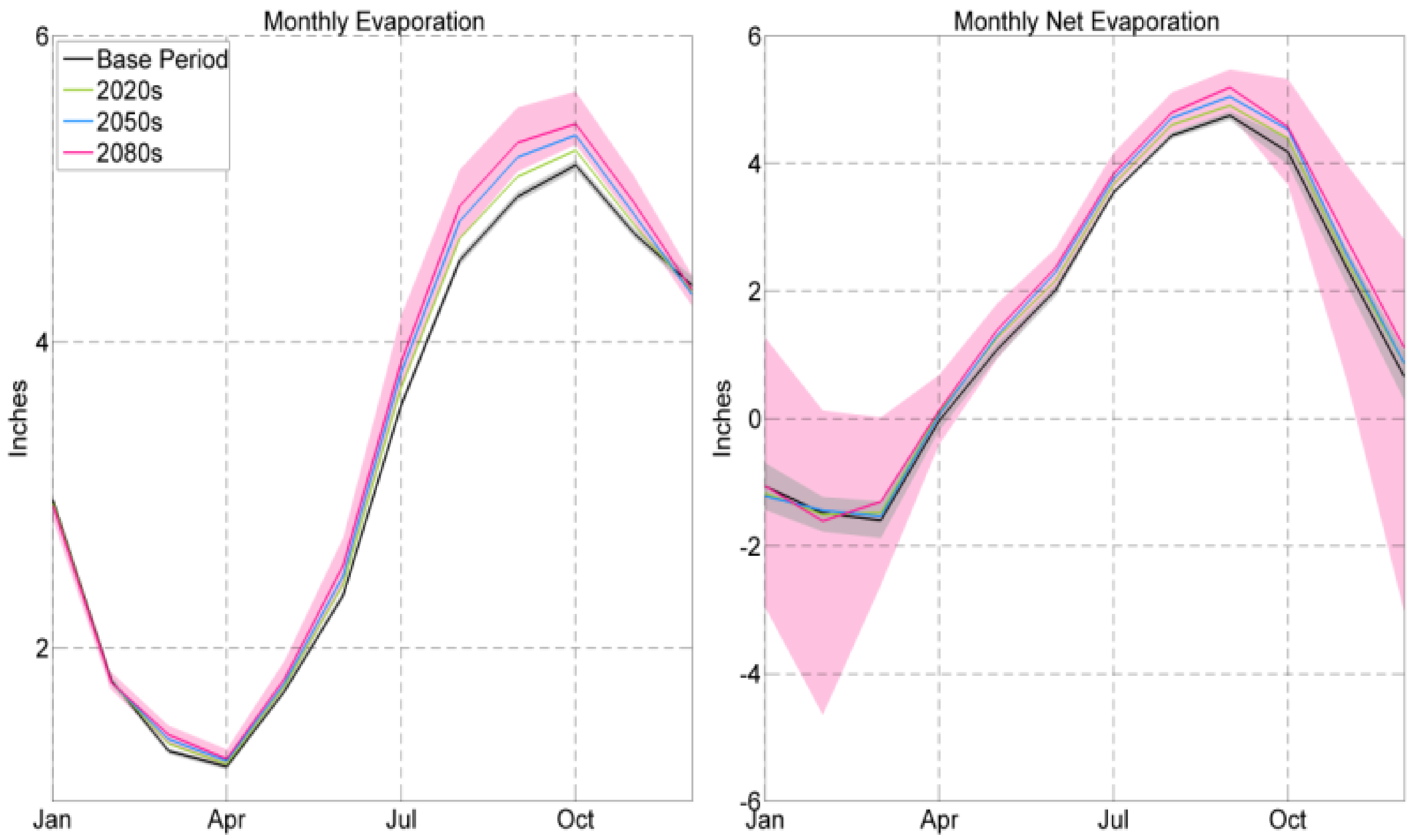
Future Projections of Lake Tahoe Evaporation

- CRLE forced with future climate
  - BCSD monthly average temperature (112 projections bias corrected to Tahoe City)
  - estimated solar radiation (empirical TR equation calibrated to Tahoe City measured solar),
  - estimated humidity (based from monthly climatology of measured dewpoint depression at Tahoe City [Ko = Tmin-Tdew])
  - Lake Tahoe ensemble median and 5th and 95th percentile annual precipitation, temperature, reservoir evaporation, and net evaporation.



Future Projections of Lake Tahoe Evaporation

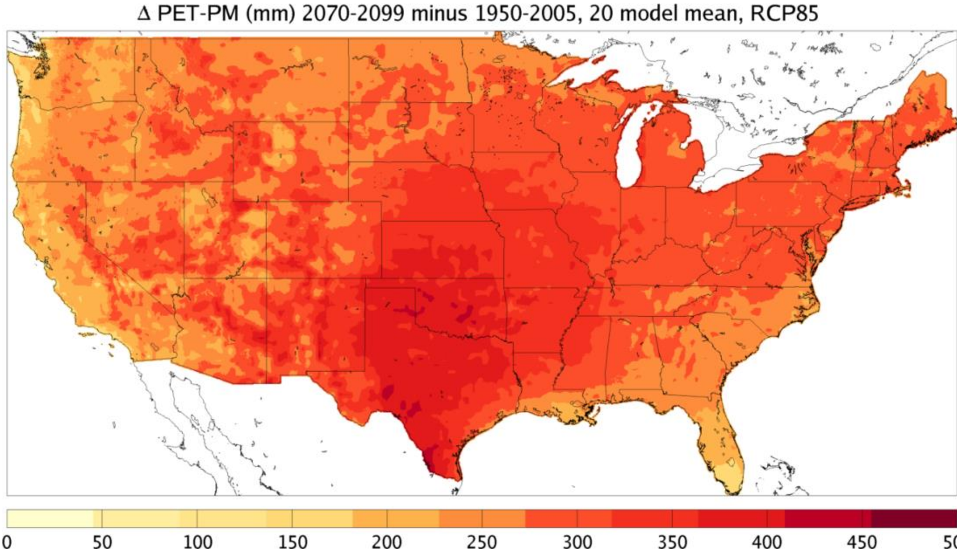
- Lake Tahoe mean monthly ensemble median and 5th and 95th percentile reservoir evaporation and net evaporation.



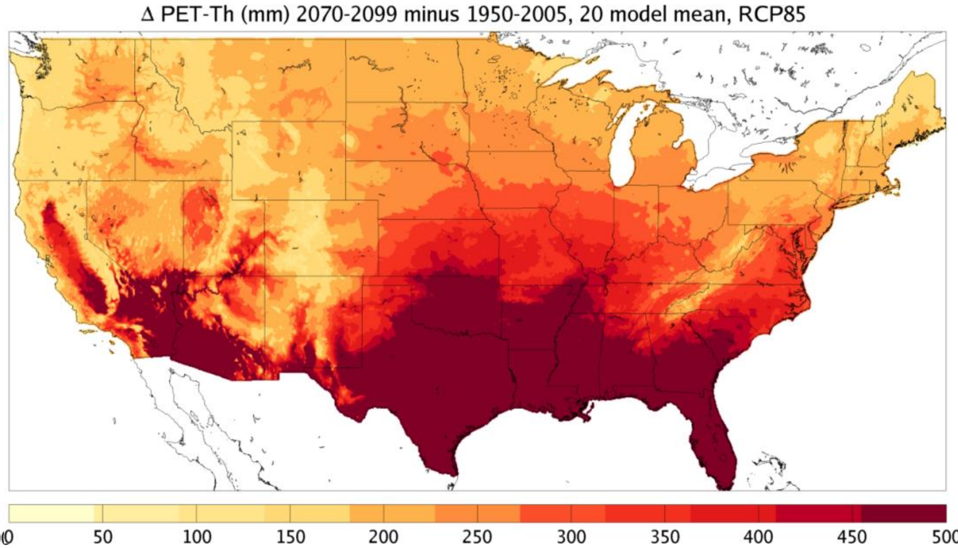
Some thoughts

- Estimating future evaporation is hard
  - Are there other data sources or ideas folks have that anyone to help constrain Tahoe evaporation estimates?
- Better to use a physical model and some empirically derived forcings, than an empirical model based on temperature alone..
- Look forward to using future climate projections with archived variables need to estimate E and PET using physical models (Rs, RH, Wind, Temp)

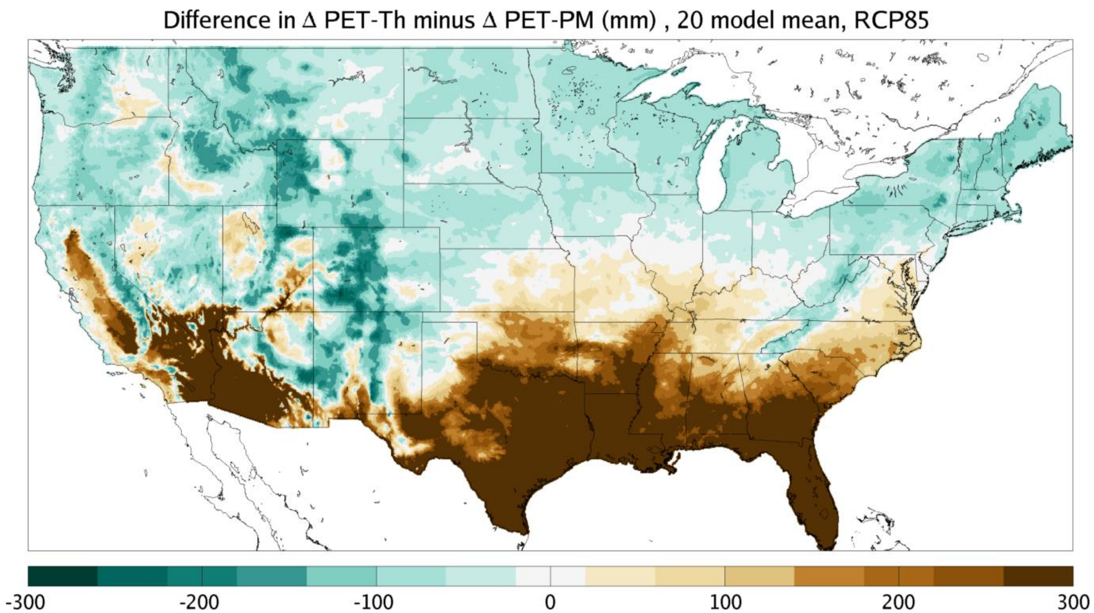
Some Prelim. Results by J. Abatzoglou - MACA



ASCE-PM ETo



Thornthwaite ETo



Big implications on future projections of drought indices depending on what ETo is used in various drought indices

Thornthwaite ET minus ASCE-PM ETo

TH Higher in low elevations, and lower at higher elevations..super temperature sensitive

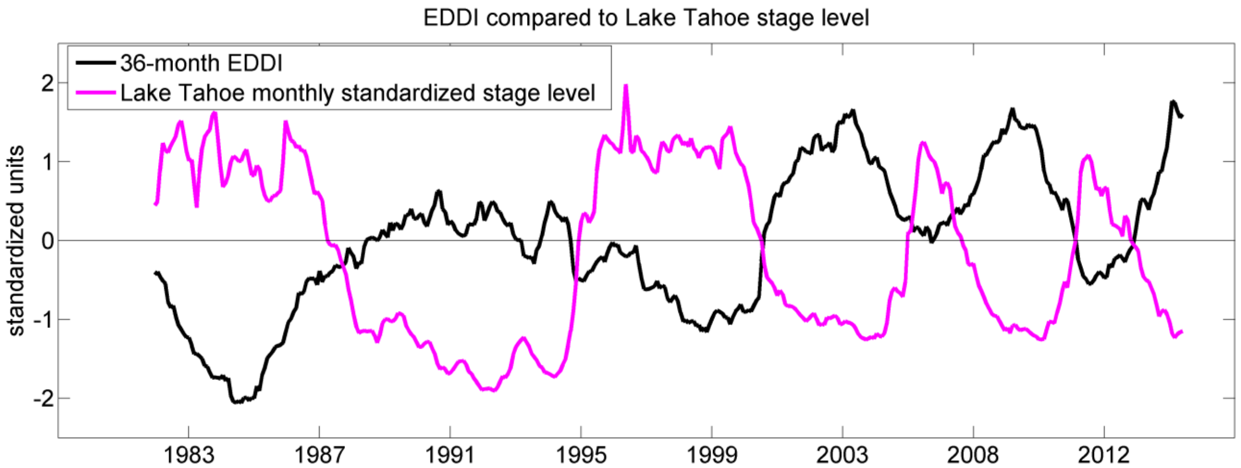
Evaporative Demand Drought Indices and Lake Levels?

- Higher PET is due to higher temps, more solar radiation, and lower RH.. Typical of drought conditions when we have low actual ET (i.e. complementary theory)
  - No precipitation is used. EDDI is simply an anomaly of physically based Penman-Monteith PET for a grass reference surface

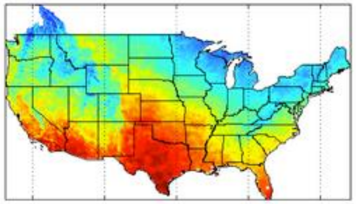
- Lake Tahoe stage levels take ~3 to 4 years to respond to extended drought

- 36-month EDDI correlates well (inversely) to standardized lake levels

- During extended droughts with colder than normal temperatures, EDDI may not fully capture severity (i.e. early 90's)



Smal part of Dan McEvoy's PhD work



Multivariate Adaptive Constructed Analogs(MACA) Statistical Downscaling Method

University of Idaho

HOME | ABOUT THE DATA | ANALYSIS TOOLS | GUIDANCE | GET THE DATA | CONTACT

The MACA Method:

Short Description:

Short Lecture Videos:

MACA Step 1: Common Grid

MACA Step 2: Epoch Adjustment

MACA Step 3: Coarse Bias Correction

MACA Step 4: Constructed Analogs

MACA Step 5: Epoch Replacement

MACA Step 6: Fine Bias Correction

Differences between MACAv1 and MACAv2:

REACCH Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

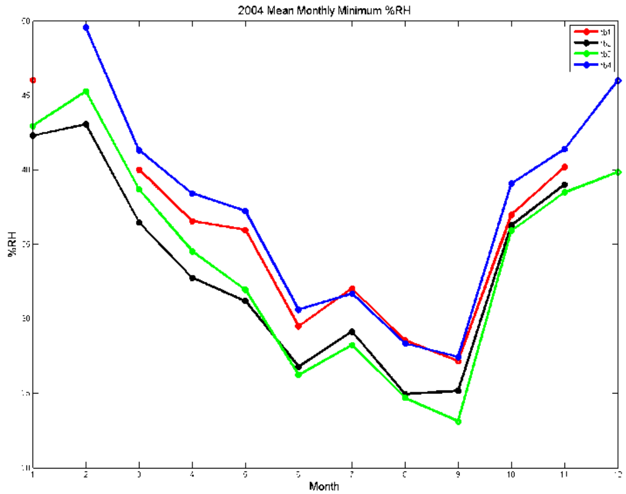
CIRC Climate Impacts Research Consortium

NKN Northwest Knowledge Network

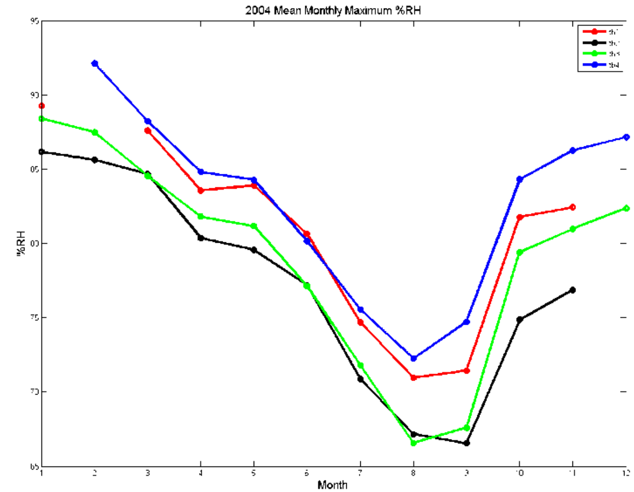
NW CSC Northwest Climate Science Center

Some Ideas

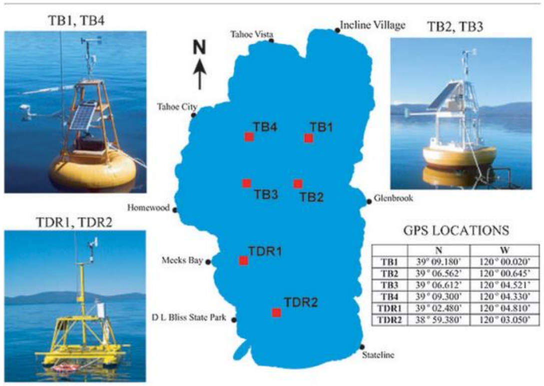
- Evaluate NASA buoy weather data the period of record at each buoy to better understand evaporation drivers and over water Temp, Tdew, winds, surface temperature, and differences
- Would be excited to collaborate with Simon Hook or others on such an evaluation (I have grad students!! and some $$..)..
    - Will work for free to learn and make models better…



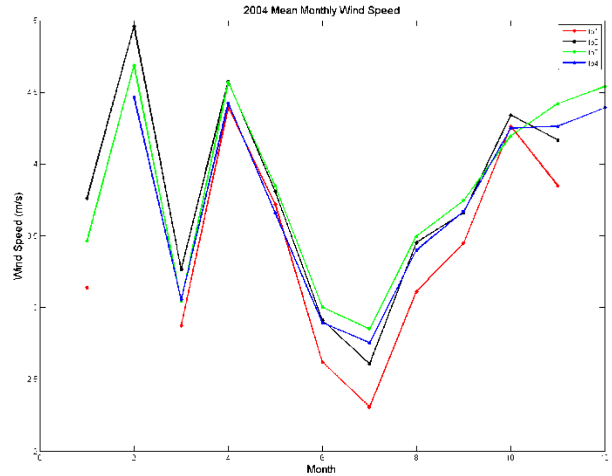
Min Daily %RH



Max Daily %RH



	N	W
TB1	39° 09.180'	120° 00.020'
TB2	39° 06.562'	120° 00.645'
TB3	39° 06.612'	120° 04.521'
TB4	39° 09.300'	120° 04.330'
TDR1	39° 02.480'	120° 04.810'
TDR2	38° 59.380'	120° 03.050'

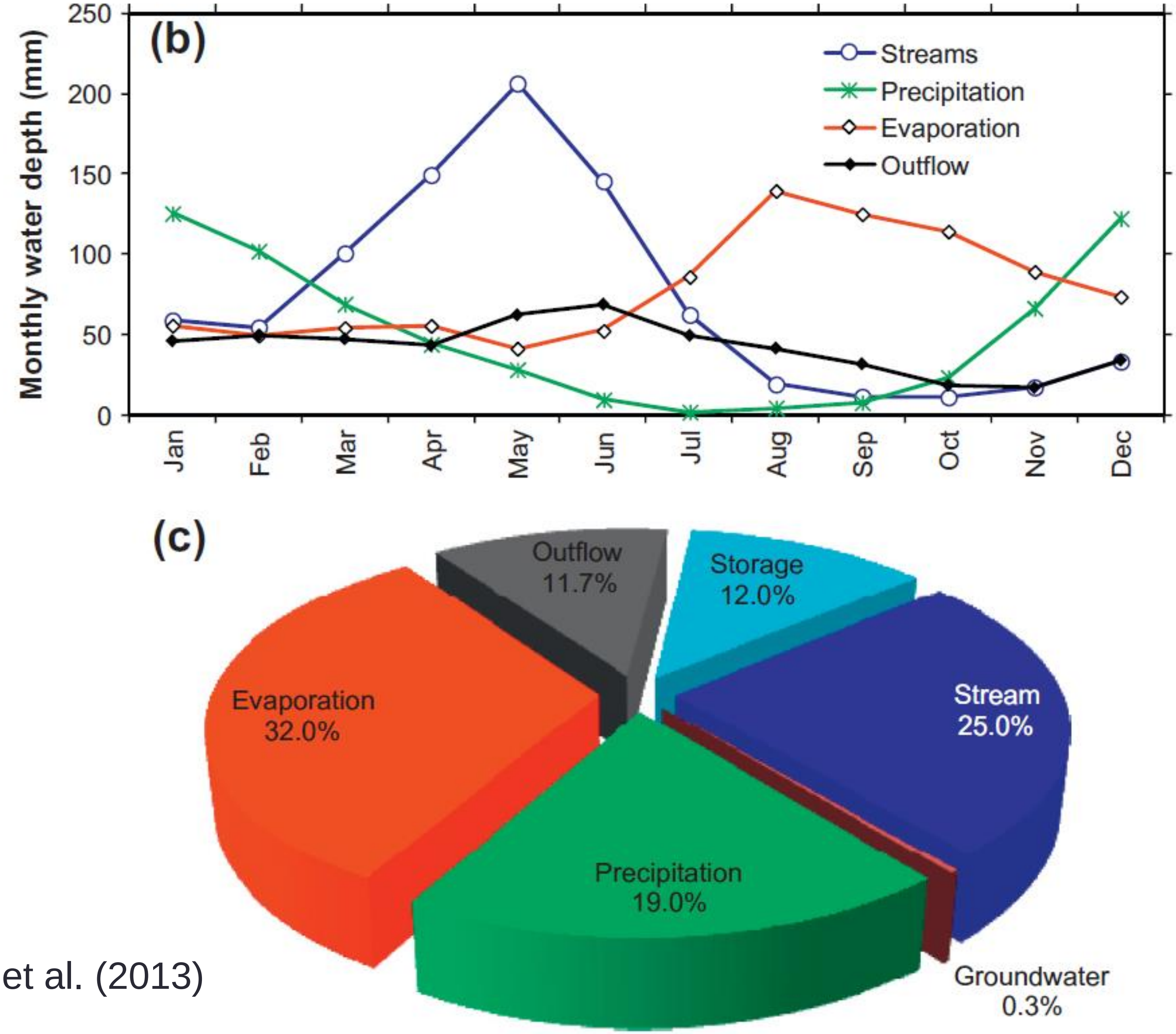


Mean Wind

Some Other Ideas

- Look at drivers and feedbacks in potential ET and PPT projections
  - highlight physical processes and perhaps dependencies/strengths of models and projections
- Look at the MACA dataset by U of Idaho / DRI (Abatzoglou and Brown, 2012) for physically based ETo projections? (i.e. Penman-Monteith.. not based on temp alone..)
- Collaborate with others to explore approaches for estimating future evaporation using future surface temperature, wind, humidity and apply aerodynamic methods
- Compare other future evaporation estimates to CRLE estimates. Use new forcings in CRLE or other models (aerodynamic) and compare.
- Open source data/model policy… we need to share our data/models with others to advance our science in the basin
  - Will help more way more than hurt
  - Collaboration with others is our key to success
- Set up a data/model portal for Tahoe researchers
  - If sensitive, or you want to publish first with the data, say it...and it will be respected.
  - If we sit on the data and wait to share until published, science is going to move slowly..

Thanks – Questions?



Sahoo et al. (2013)

Water Surface Energy Balance

- Most widely used in research, and is the most data intensive and complex approach due the need to consider the entire water body as a control volume rather than just the surface in the case of a land surface energy balance

- Evaporation can estimated as a residual of the water body energy balance

$$LE = R_n + Q_v + Q_b - H - Q_x - Q_w$$

- *LE* is the latent energy consumed for evaporation
- R_n is the net radiation
- Q_v is the net advected energy to the water body from surface and groundwater inflows and outflows, and direct precipitation (dependent on temperature and amount of flux…*linked to water budget!*)
- Q_w is the energy advected by evaporating water (dependent on temperature and amount of evaporating water)
- Q_b is the energy exchange from bottom sediments to the water body,
- *H* is the energy convected and conducted from the water body to the air as sensible heat
- Q_x is the energy that is stored in the water body

Water Balance

- Evaporation can be expressed as a residual of the water budget volume or depth per unit time following the continuity equation for a generalized water body as

$$E = P + SW_{in} + GW_{in} - SW_{out} - GW_{out} - B - \Delta S$$

- P is direct precipitation on the water surface
- SW_{in} and GW_{in} are surface and groundwater inflows
- SW_{out} and GW_{out} are surface and groundwater outflows
- B is bank storage
- dS is the change in storage

Aerodynamic / Bulk Mass Transfer

- Dalton's (1802) general form of the mass transfer equation can be expressed as

$$E = M(e_s^* - e_a)$$

- *E* is the evaporation rate,
- e_s is the saturation vapor pressure at the temperature of the water surface
- e_a is the actual vapor pressure of the air
- M is the mass transfer coefficient and is a function of wind speed, atmospheric stability, surface roughness, thermally induced turbulence, barometric pressure, and the density and viscosity of the air .

Crop reference *ET using Physically Based Evaporative Demand – ASCE Penman-Monteith equation*

$$ET_{rc} = \frac{\Delta}{\Delta + \gamma(1 + C_d U_2)} \frac{R_n - G}{\lambda} + \frac{\gamma}{\Delta + \gamma(1 + C_d U_2)} \frac{C_n}{T + 273} U_2 (e_s - e_a)$$

Physically based equation

Advective component:

- Temperature
- Wind Speed
- Humidity

R_n = net radiation (shortwave + longwave)
G = ground heat flux (assumed to be zero)
T = mean daily temperature
U_2 = mean daily wind speed at 2-m
e_s = saturation vapor pressure $((e_{s\_tmax}+e_{s\_tmin})/2)$
e_a = actual vapor pressure (from q and surface pressure)
λ = latent heat of vaporization
Δ = slope of saturation vapor pressure-temperature curve
γ = psychrometric constant
C_n = 900 (grass reference)
C_d = 0.34 (grass reference)

Radiative component:

- SW radiation
- LW radiation
- Ground heat flux

(Allen et al. 1998, 2005)

Meteorology and Climate

- Required variables
  - ASCE-PM – daily temperature, solar radiation, dewpoint, windspeed
  - CRLE – monthly temperature, solar radiation, dewpoint

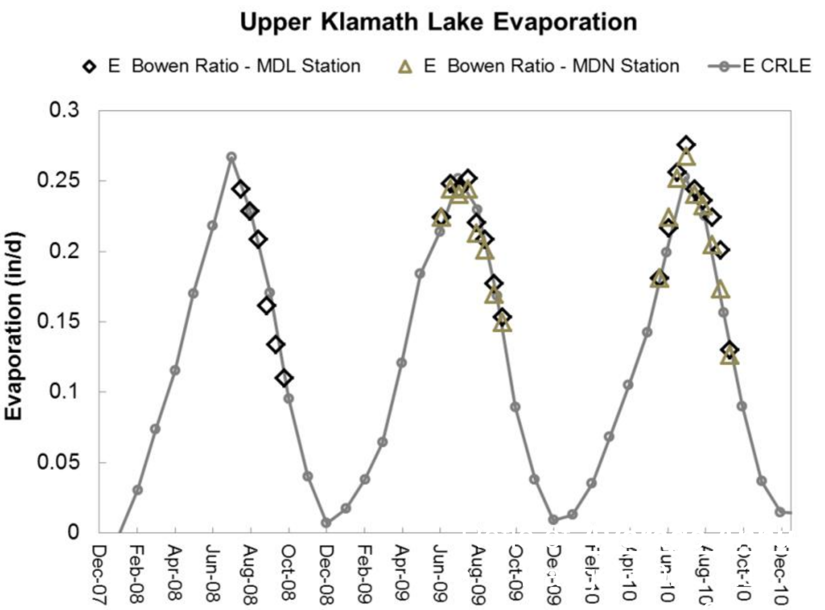
- Daily solar radiation estimated using Thornton and Running (1999) equation calibrated specifically to each basin
  - Solar radiation based on empirical relationship between daily $T_{max} – T_{min}$
  - Calibrated Thornton and Running equation coefficients to measured solar radiation data at 44 agricultural weather stations using Monte Carlo uniform random search for each basin

- Dewpoint and windspeed estimated using spatially distributed agricultural station measured mean monthly wind speed and dewpoint depression (K_o=Tmin - Tdew)
  - Over ***550*** agricultural weather station datasets were acquired, QAQCed temp, wind, and humidity and used for creating spatial distributions (AgriMet, CIMIS, NICE Net, CoAgMet, AZMET, USU AgMet, HighPlains-AWDN, CoAgMet, New Mexico State, U of Wyoming, others)
  - Spatially distributed mean monthly windspeed and Ko surfaces were averaged to HUC8s, and assigned to respective COOP Met Nodes

Evaluation of CRLE

Evaluated CRLE model for historical periods - Compares well to previous estimates of evaporation (water budget, mass transfer, Bowen ratio energy balance, eddy flux)

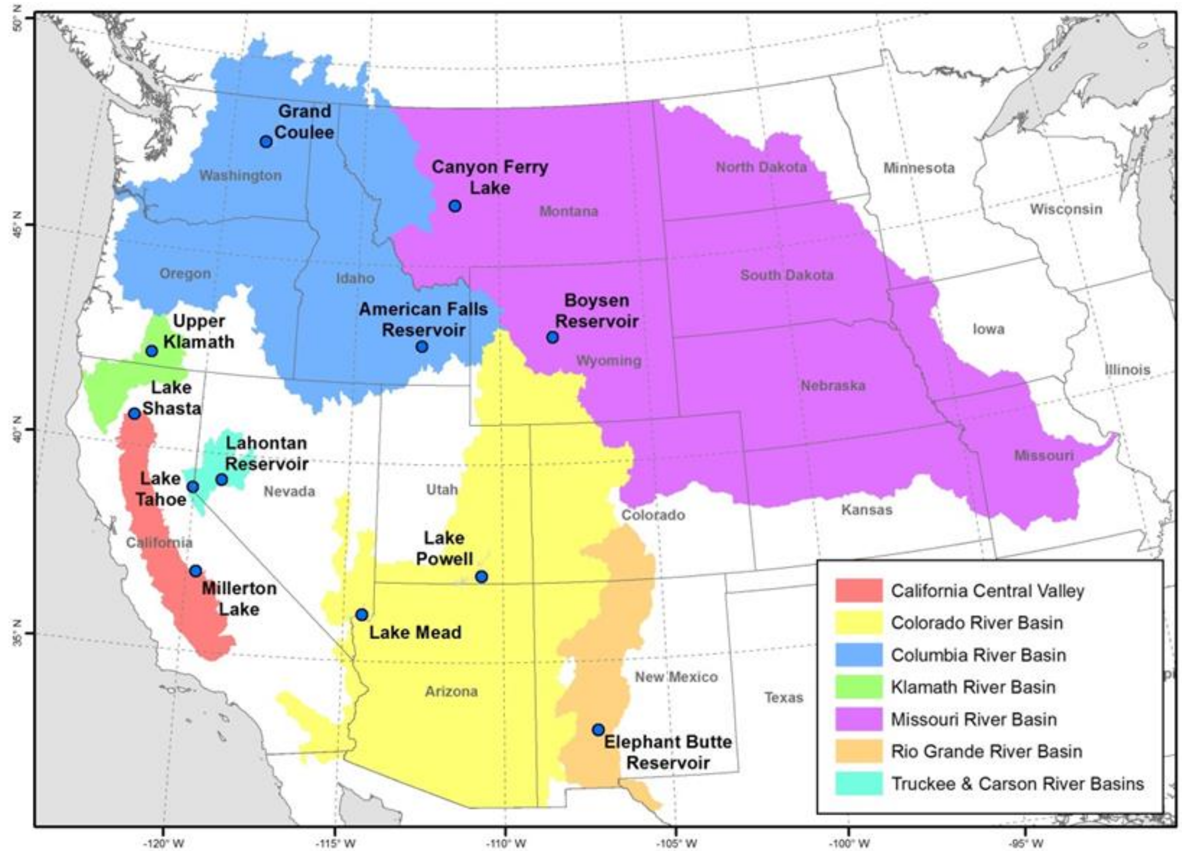
Seasonal – Upper Klamath Lake
USGS Bowen Ratio Comparison,
Stannard (2013)



Open Water Evaporation Modeling

- The Complementary Relationship Lake Evaporation (CRLE) model (Morton et al., 1985) was utilized to simulate open water evaporation from 12 reservoirs / lakes

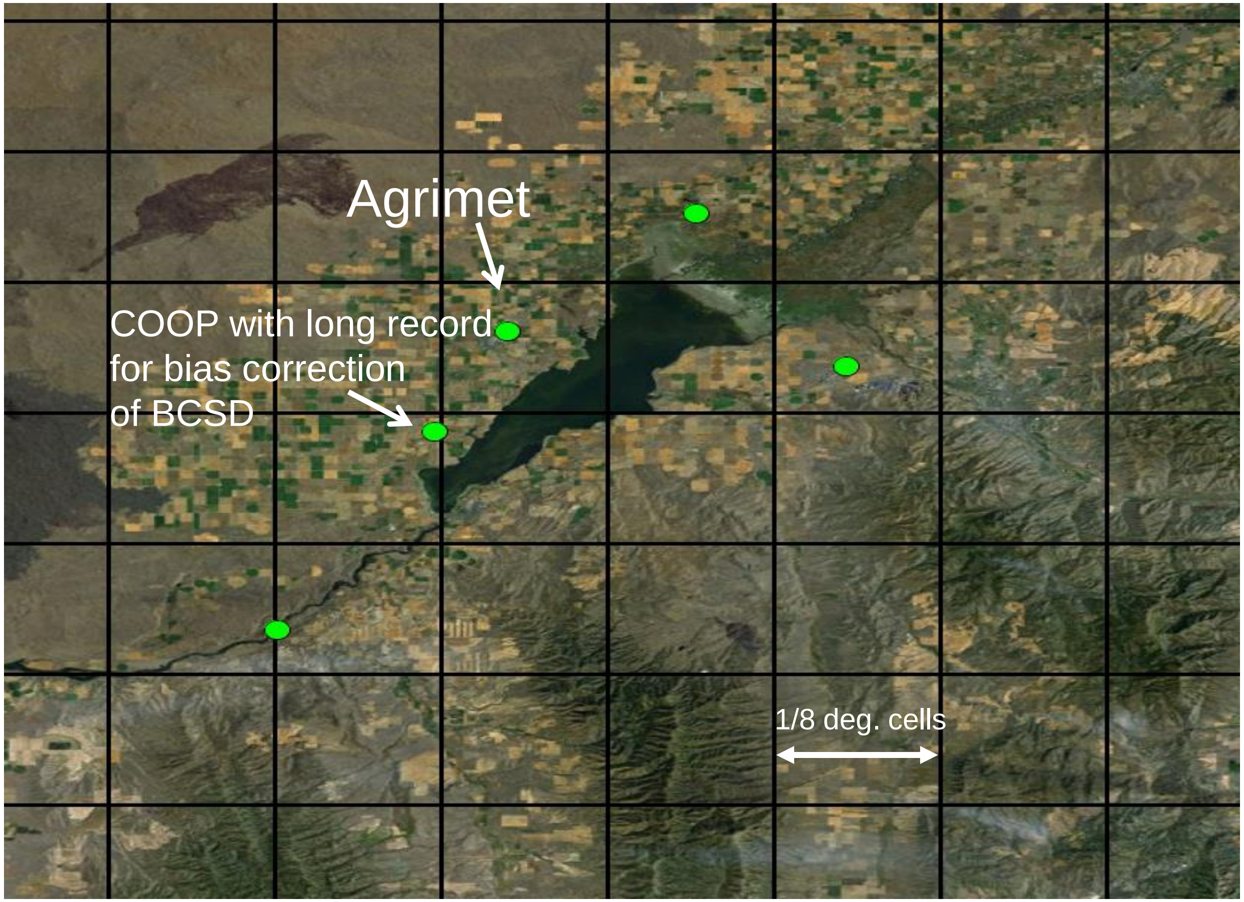
  - Energy balance based approach
  - Takes into account seasonal heat storage leading to the potential shift in seasonal evaporation
  - Relies on measured or estimated climate observations (air temp, solar radiation, dewpoint)
  - Relatively insensitive to the contrasts between the open water and land environments



Application of CRLE

CRLE model Met Node example: American Falls Reservoir, Columbia Basin

- Used COOP/NWS station for bias correction of Maurer and BCSD data
- Estimated daily (Tmax-Tmin) and solar using bias corrected Maurer and future BCSD
- Estimated mean monthly dewpoint depression from nearby Agrimet station
- CRLE was forced with transient future climate using 112 different GCM projections

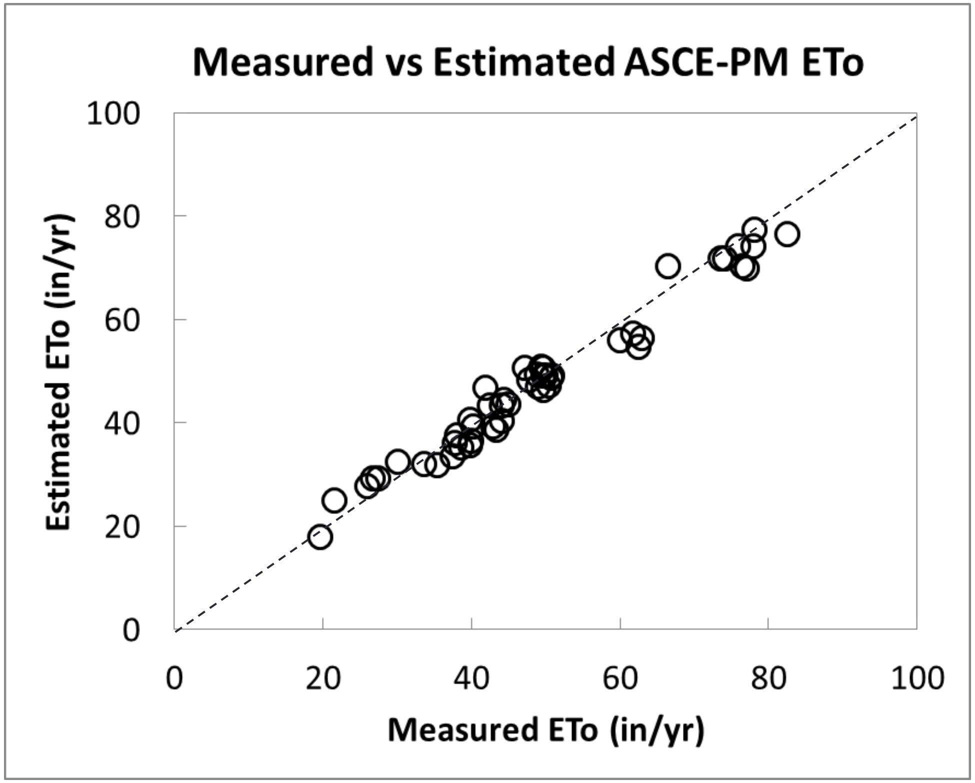


Evaluation of Estimated ASCE-PM Historical ET_o

- Compared estimated ASCE-PM reference ET (ET_o) to measured ET_o at ***50*** agricultural weather station – COOP/NWS station pairs
- Estimated ET_o using Maurer T_{max} and T_{min}, estimated solar, and mean monthly spatially distributed dewpoint and windspeed
- Estimated ET_o is robust at annual and monthly time scales when compared to measured agricultural station ET_o

Ratio of ***Annual*** Estimated to Measured ET_o:
- Range = 0.86 -1.15
- Average = 1.03
- STD = 0.06

Ratio of ***Monthly*** Estimated to Measured ET_o:
- Range = 0.84 -1.37
- Average = 1.03
- STD = 0.16

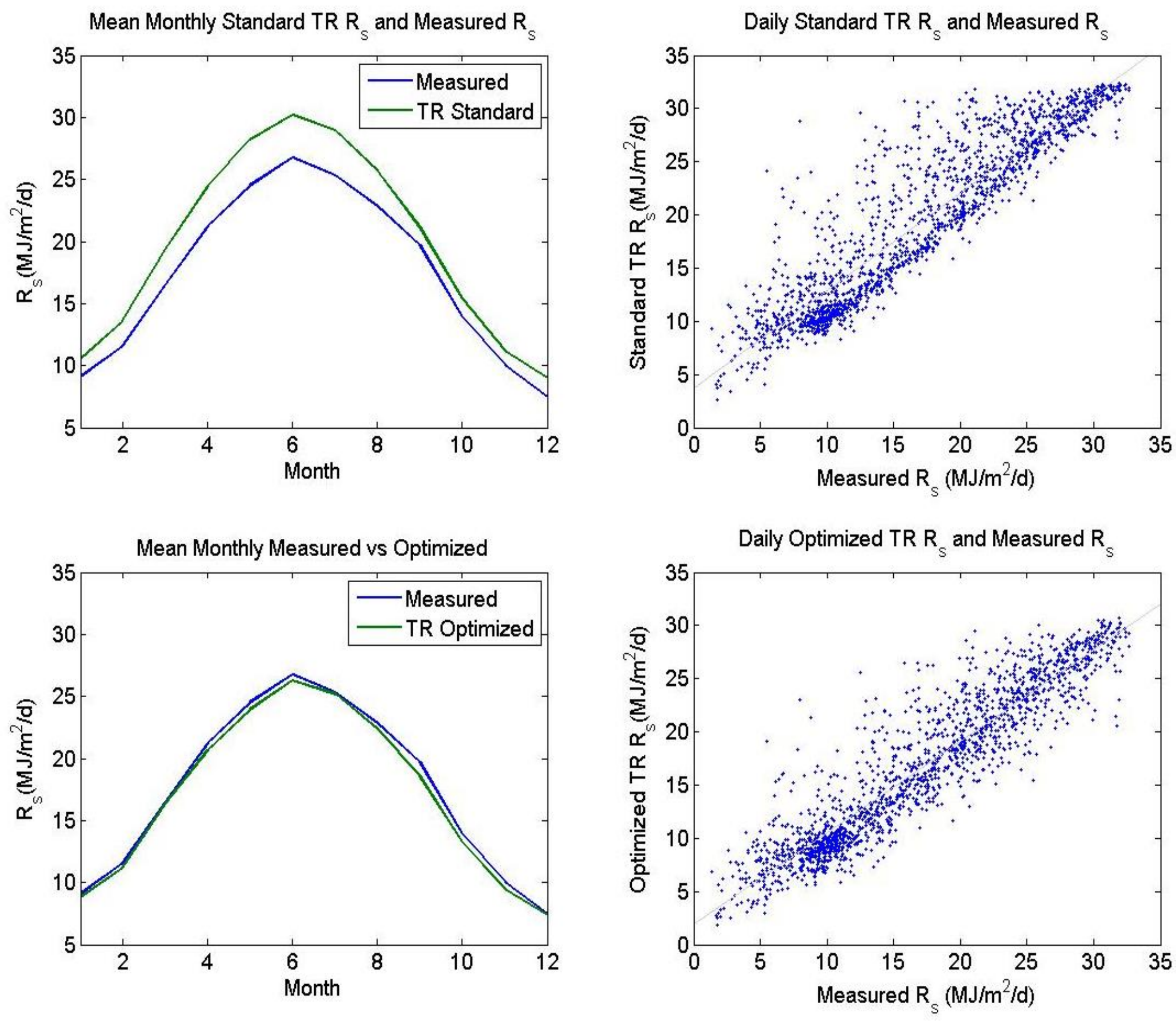


Meteorology and Climate

Upper Colorado - CoAgMet CSU Fruita Station

Standard Thornton and Running (TR) estimated solar radiation and optimized TR solar radiation using Monte Carlo uniform random search

Significant improvement results from optimization of TR equation coefficients

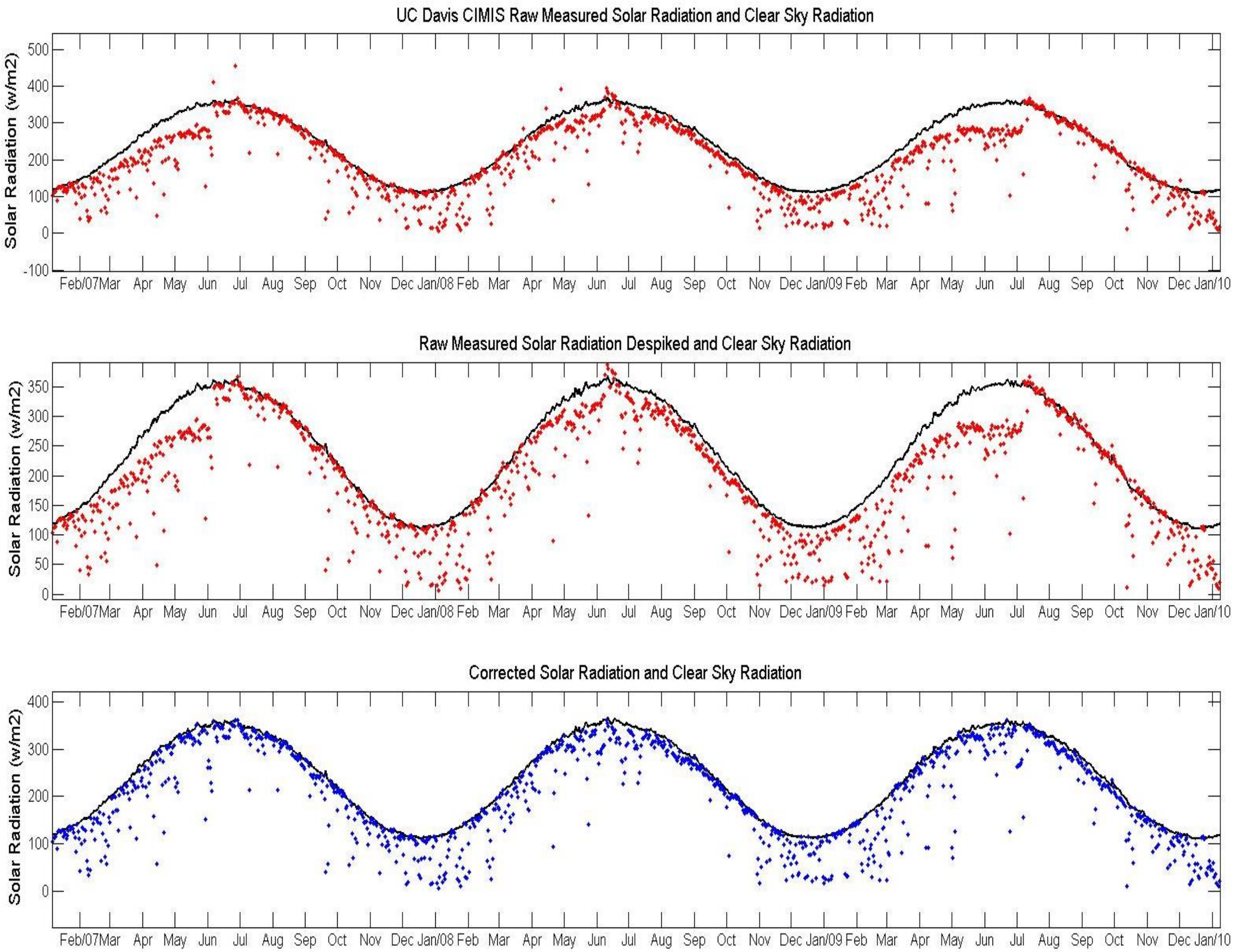


Evaluation of Estimated ASCE-PM Historical ET_o

- Compared estimated ASCE-PM reference ET (ET_o) to measured ET_o at ***__50__*** agricultural weather station – COOP/NWS station pairs
- ***__But FIRST__*** - QAQC of solar radiation, temperature, humidity, and windspeed is ***__REQUIRED__*** prior to comparing estimated ETo to measured ETo

Example of QAQC process of Solar Radiation at UC Davis CIMIS station

Based adjustments on ratios between theoretical clear sky solar radiation and top percentiles of measured data



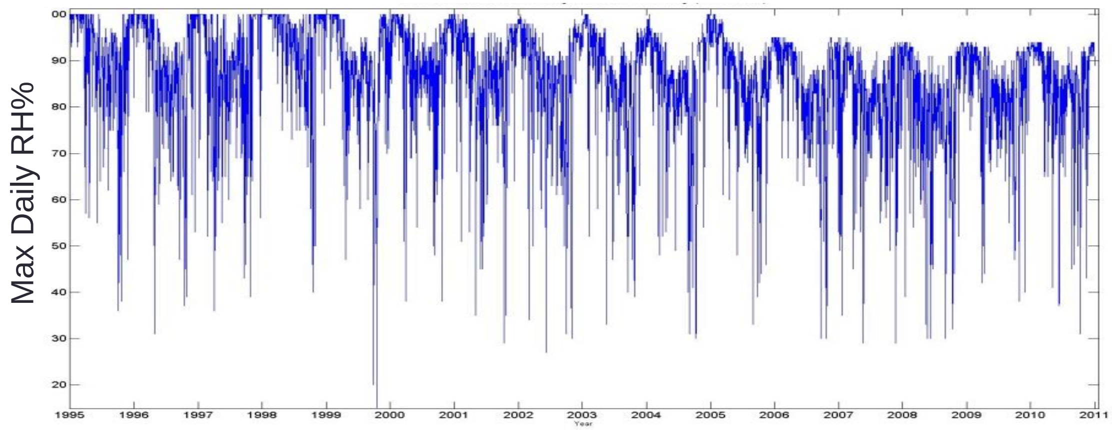
Evaluation of Estimated ASCE-PM Historical ET_o

- Compared estimated ASCE-PM reference ET (ET_o) to measured ET_o at ***<u>50</u>*** agricultural weather station – COOP/NWS station pairs
- ***But FIRST*** - QAQC of solar radiation, temperature, humidity, and windspeed is ***REQUIRED*** prior to comparing estimated ETo to measured ETo

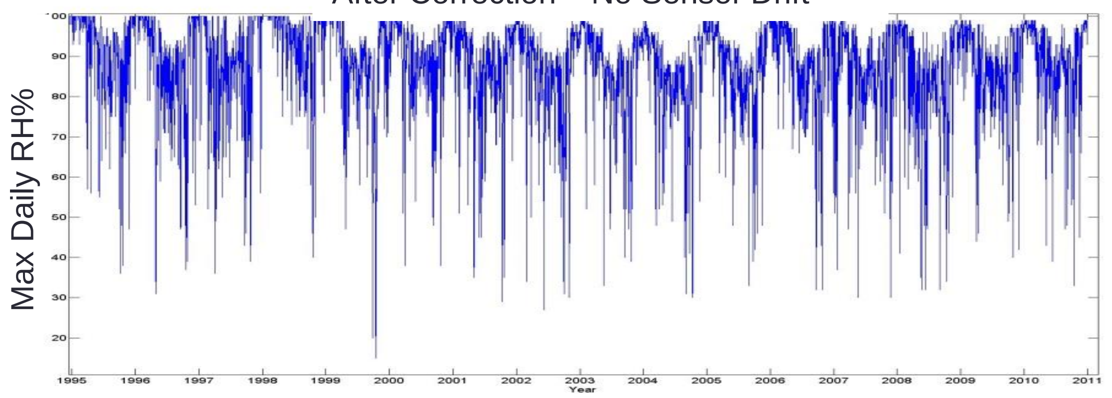
Example of QAQC process of Max. Daily RH% at UC Davis CIMIS station

Base adjustments on ratios between theoretical clear sky solar radiation and top percentiles of measured data

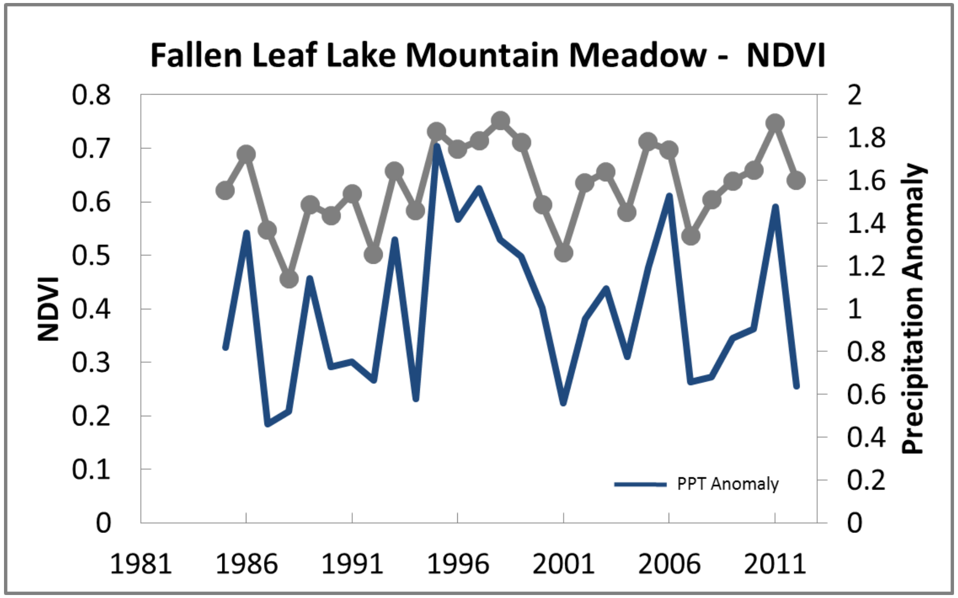
Before Correction – Sensor Drift



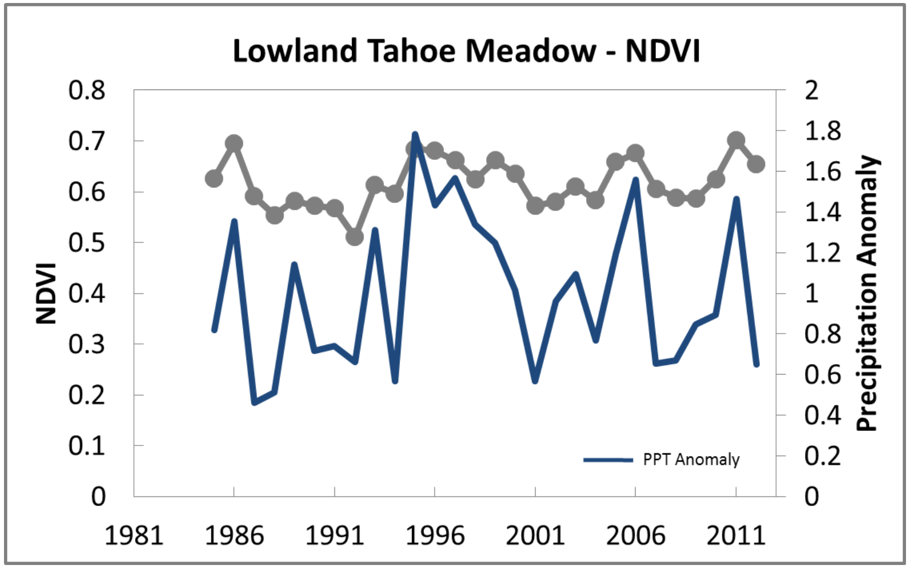
After Correction – No Sensor Drift



Topographic Driven Discharge Meadow Near Fallen Leaf Lake



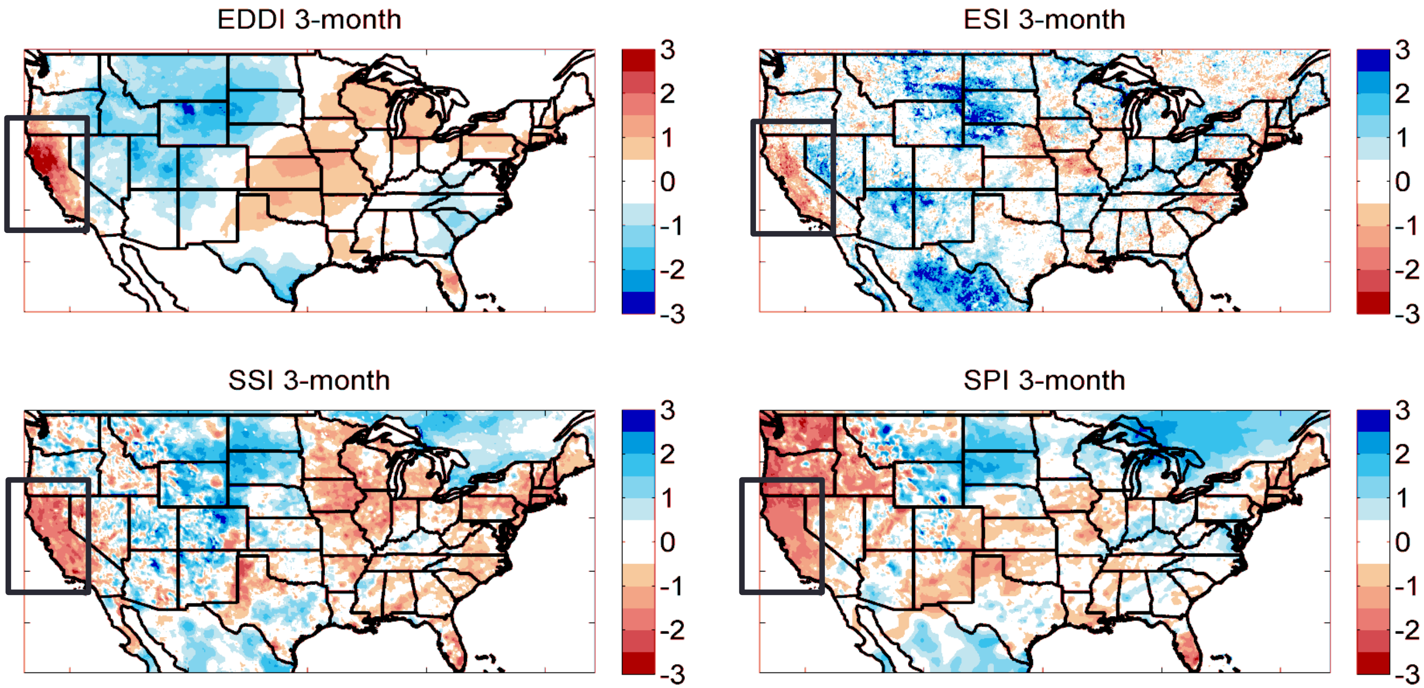
Lake Tahoe Valley Floor Meadow



Evaluating Feedbacks between ET and Potential ET – Evaporative Demand Drought Index (EDDI)

- Collaboration between NOAA/NIDIS/CIRES (Mike Hobbins, others) and DRI
- We exploit the ET and ETo feedbacks and compute the departure from the long term mean ETo per pixel
- We use NLDAS solar radiation, temperature, humidity, and windspeed to compute ETo

- If ETo is higher than the long term mean for a given time period – likely dryer and hotter
- If ETo is lower than the long term mean for a given time period – likely cooler and wetter
- Results compare well drought monitor and other indices



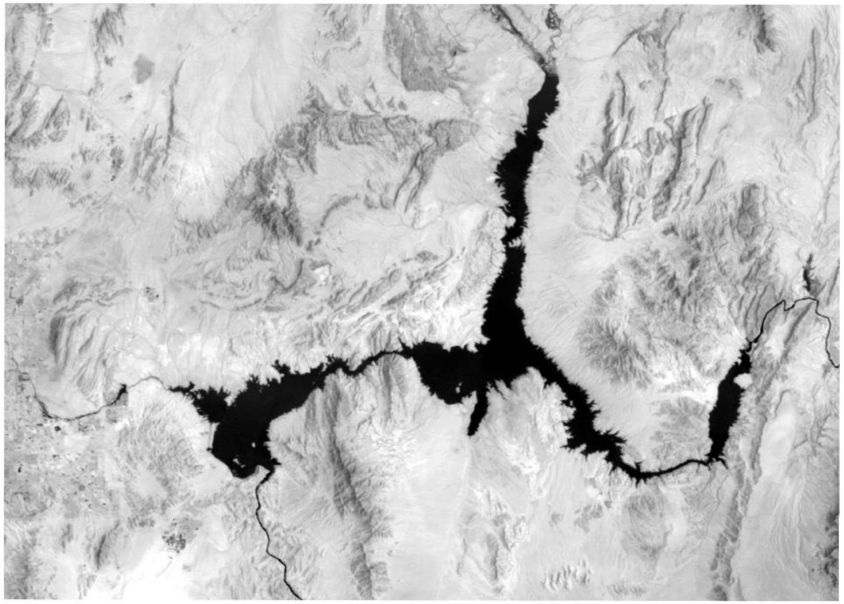
October-December, 2013

Landsat TIRS Based Open Water Evaporation

- Land surface energy balance estimates of open water evaporation are complicated by heat storage of the water body, causing a delay, and often times a reduction, in monthly evaporation compared to a Class A Pan or grass surface (i.e. no storage)

- Landsat TIRS can be used to track water "skin temperature" which can be used to estimate saturated specific humidity

- When combined with local or gridded weather data of actual specific humidity and wind speed, evaporation can be estimated using an aerodynamic – bulk mass transfer approach

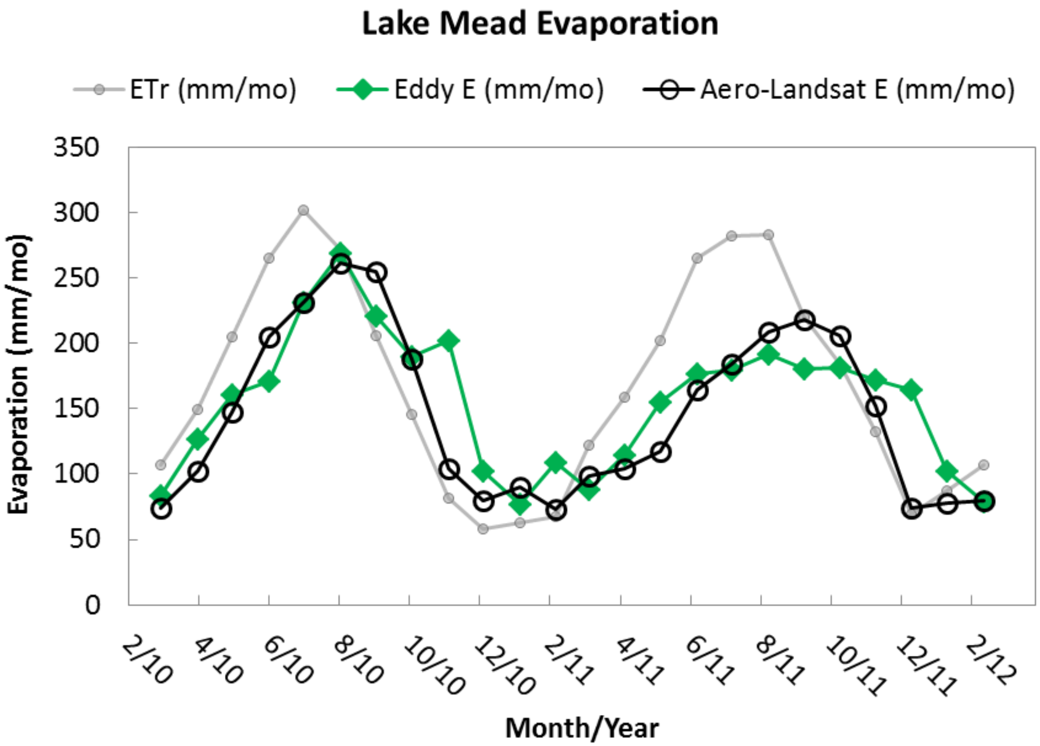


Lake Mead, NV/AZ

Landsat TIRS Based Open Water Evaporation

- Initial tests of Landsat TIRS aerodynamic evaporation from Lake Mead compared to USGS eddy flux measurements

Photo by M. Moreo - USGS

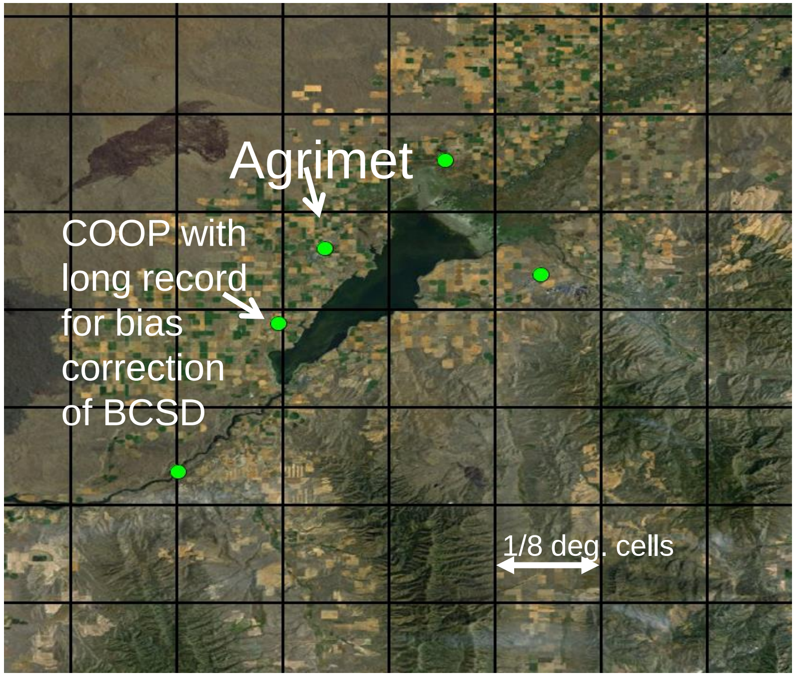


Initial results suggest that a TIRS based aerodynamic approach can simulate open water evaporation fairly well, while capturing the lag in evaporation due to the heat storage effect…

Looking into Nov, 2010 and 2011..

Meteorology and Climate

- **Use gridded climate to force irrigation water demand and reservoir evaporation models**
  - Historical - ⅛° grid, Maurer et al. (2002), 1950-1999
  - Future - BCSD CMIP3 gridded data (downscaled to the Maurer ⅛° grid)
    - 3 emission paths (B1 [low], A1B [med], A2 [high]) used
    - 16 GCMs
    - 112 climate projections
- **3 futures used to assess changes in demand through the 21st century**
  - 2010-2039 (2020s)
  - 2040-2069 (2050s)
  - 2070-2099 (2080s)
- **Further bias correction to NWS/COOP weather station data was performed to Maurer and BCSD data**
  - Account for differences in Temp and PPT (i.e. account for elevation differences between the station and ⅛° grid cell and other biases)
  - Represent valley floor conditions (i.e. where agriculture and reservoirs are)



Meteorology and Climate

- Required variables
  - ASCE-PM – daily temperature, solar radiation, dewpoint, windspeed
  - CRLE – monthly temperature, solar radiation, dewpoint

- Daily solar radiation estimated using Thornton and Running (1999) equation calibrated specifically to each basin
  - Solar radiation based on empirical relationship between daily $T_{max} – T_{min}$
  - Calibrated Thornton and Running equation coefficients to measured solar radiation data at 44 agricultural weather stations using Monte Carlo uniform random search for each basin

- Dewpoint and windspeed estimated using spatially distributed agricultural station measured mean monthly wind speed and dewpoint depression (K_o=Tmin - Tdew)
  - Over ***550*** agricultural weather station datasets were acquired, QAQCed temp, wind, and humidity and used for creating spatial distributions (AgriMet, CIMIS, NICE Net, CoAgMet, AZMET, USU AgMet, HighPlains-AWDN, CoAgMet, New Mexico State, U of Wyoming, others)
  - Spatially distributed mean monthly windspeed and Ko surfaces were averaged to HUC8s, and assigned to respective COOP Met Nodes

Landsat 8, Launched Feb 11, 2013

Many thanks to:
You
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University of Idaho

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