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Managing Water in the West

Erosion of Water Supply Predictability under Climate Change?

Levi Brekke

(Reclamation, Technical Service Center, Denver, CO)

U.S. Department of the Interior
Bureau of Reclamation

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Acknowledgments

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  - Reclamation R&D and four region offices, NRCS, NWS RFCs
- Project Team
  - Reclamation TSC (L. Brekke, T. Pruitt)
  - NRCS (D. Garen)
  - NWS CBRFC (K. Werner) and NWRFC (D. Laurine)
- Collaborators (methods review, model/data sharing)
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  - Reclamation PN (M. Mellema)
  - Bonneville Power Administration (N. Stephan)
  - NWS CNRFC, MBRFC

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Research Question

- Does climate change with warming lead to a reduction in water supply predictability? If yes, at what rate?

- What are the ramifications for:
  - longer-term planning?
  - contemporary operations?

- What forecast model-maintenance procedures might be applied to minimize reductions in predictability?

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Context

- NRCS, NWS RFCs, USACE and Reclamation all issue spring-summer runoff forecasts in the CSRB, based on statistical models.
- These forecasts inform monthly operations scheduling.
- General Attributes
  - Forecast Periods: Apr-Jul, other spring-summer periods
  - Forecast Issue Months: (leading up to Period) Jan, Feb, Mar, Apr …
  - Common Predictors at time of Issue (ignoring others for now…):
    - P: antecedent precipitation (~October-to-date)
    - SWE: Snow water equivalent (~at time of Issue)
  - Prediction model
    - Regression equation: Runoff modeled as function of P and SWE
    - Calibrated to reflects historical relationships

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Research Approach

1. Select Climate Projections, 1950-2099.

2. Create projected basin hydroclimates (P, SWE, Runoff) from 1950-2099 using process-based hydrologic modeling.

3. Enact forecast-model development *and* application procedures, through time, within the basin hydroclimates from (2). Follow current frequency of model maintenance (~decadal).

4. Evaluate model application skill through time as climate changes.

5. Explore ways to preserve skill (e.g., other predictors, different update frequency, etc). Evaluate by re-doing (3) and (4).

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Starting Points

- Study Basins
- Climate Projections Data
- Hydrologic Model
- Forecast Modeling Approach

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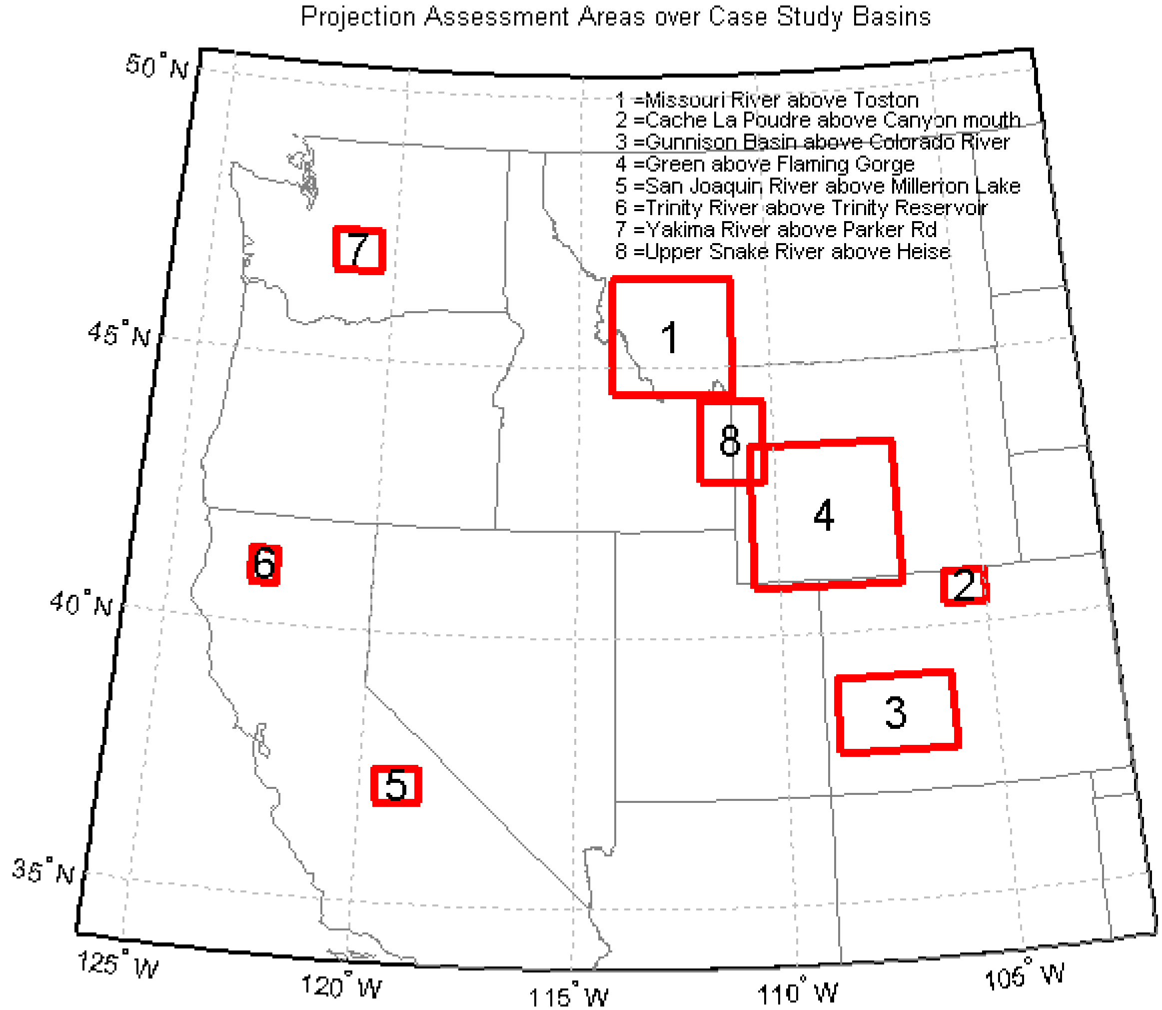
Study Basins

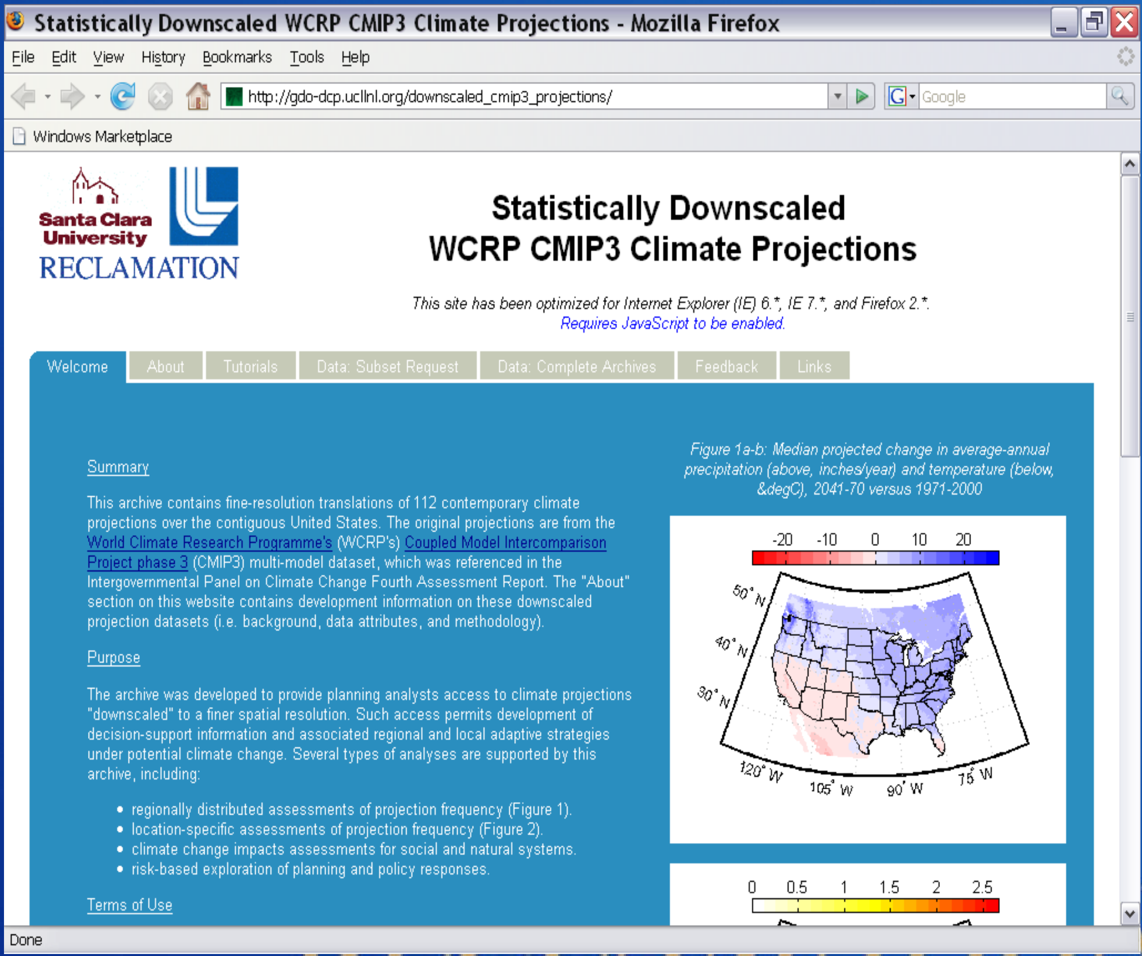
1. Missouri above Toston
2. Cache La Poudre above Canyon Mouth
3. Gunnison above Colorado River
4. Green above Flaming Gorge
5. San Joaquin above Millerton Lake
6. Trinity above Trinity Reservoir
7. Yakima above Parker Road
8. Upper Snake above Heise



Climate Projections Data Archive (Bias-corrected, Spatially Downscaled)

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/

- Developers
  - Santa Clara University (Ed Maurer)
  - Reclamation
  - LLNL
- Funding
  - Reclamation
  - DOE NETL



Archive Scope

- 112 Projections
  - Range of models, emission scenarios, and initializations
- Membership Criteria:
  - Emissions: ~low, medium and ~high paths (B1, A1b, A2)
  - Models: those that had simulated B1, A1b and A2, and 20th century, as of June 2007.
  - Initializations: all initial conditions used for a given model-emissions combination (i.e. "runs").

#	WCRP CMIP3 Model I.D.	# A1b	# A2	# B1
1	BCCR-BCM2.0	1	1	1
2	CGCM3.1 (T47)	1…5	1…5	1…5
3	CNRM-CM3	1	1	1
4	CSIRO-MK3.0	1	1	1
5	GFDL-CM2.0	1	1	1
6	GFDL-CM2.1	1	1	1
7	GISS-ER	1	2, 4	1
8	INM-CM3.0	1	1	1
9	IPSL-CM4	1	1	1
10	MIROC3.2(medres)	1…3	1…3	1…3
11	ECHO-G	1…3	1…3	1…3
12	ECHAM5/MPI-OM	1…3	1…3	1…3
13	MRI-CGCM2.3.2	1…5	1…5	1…5
14	CCSM3	1…4	1…3, 5…7	1…7
15	PCM	1…4	1…4	2…3
16	UKMO-HadCM3	1	1	1

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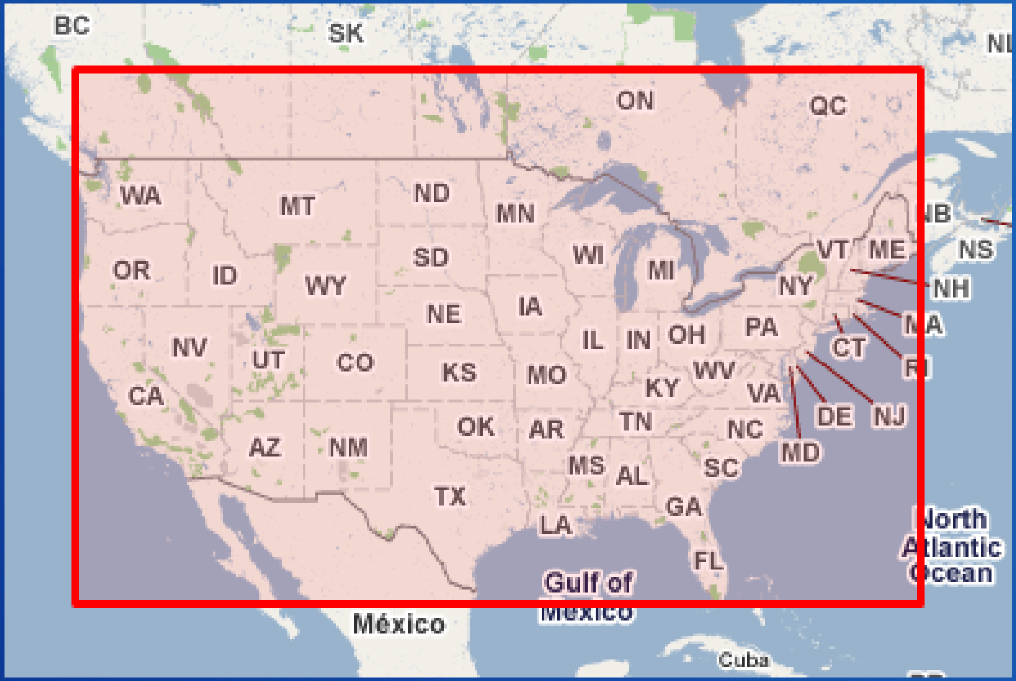
Archive Data Attributes

- Variables:
  - Precipitation Rate (mm/day)
  - Mean Daily Temperature (°C)
- Temporal Coverage and Resolution
  - 1950-2099, monthly
- Spatial Coverage and Resolution
  - Contiguous U.S., 1/8° (~12km x 12 km)



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Model Tools, Frameworks

- Hydrology Model
  - SacSMA/Snow17
  - As applied by NWS RFCs in case study basins
  - Translatinng monthly BCSD climate projections into SacSMA inputs:
    a. GIS for spatial reconciliation, BCSD grid to SacSMA topographic “areas”
    b. Wood et al. 2002 (Maurer 2007) for time-disaggregation from monthly BCSD to 6-hourly SacSMA input

- Water Supply Forecast Modeling Framework
  - Consistent with NRCS, USACE, and CBRFC methods
    - PC Regression
  - Notable differences:
    - mean-area predictors, not point (station) predictors
    - preset predictors, no search for “optimal predictors”

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Preliminary Work

- Climate Projections Selection
- Simulating Basin Hydroclimates
  - Upper Missouri example
  - w/out adjusting potential evapotranspiration
  - Subset of Archive projections (A1b)
- Adjusting potential evapotranspiration (PET) in the SacSMA hydrology models

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Climate Projections Selection

- Given
  - weak basis for culling models or paths → keep all
- Selection Goal
  - ensemble that represents breadth of information
- Options
  - All available projections (multi-model, -path,-run)
  - Emissions-specific set (multi-model, -run)
  - mixed-Emissions set (multi-model, -run)
- Approach: include All Archive projections if computational load isn't excessive; otherwise only A1b

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All vs. A1b: ensemble characteristics are similar

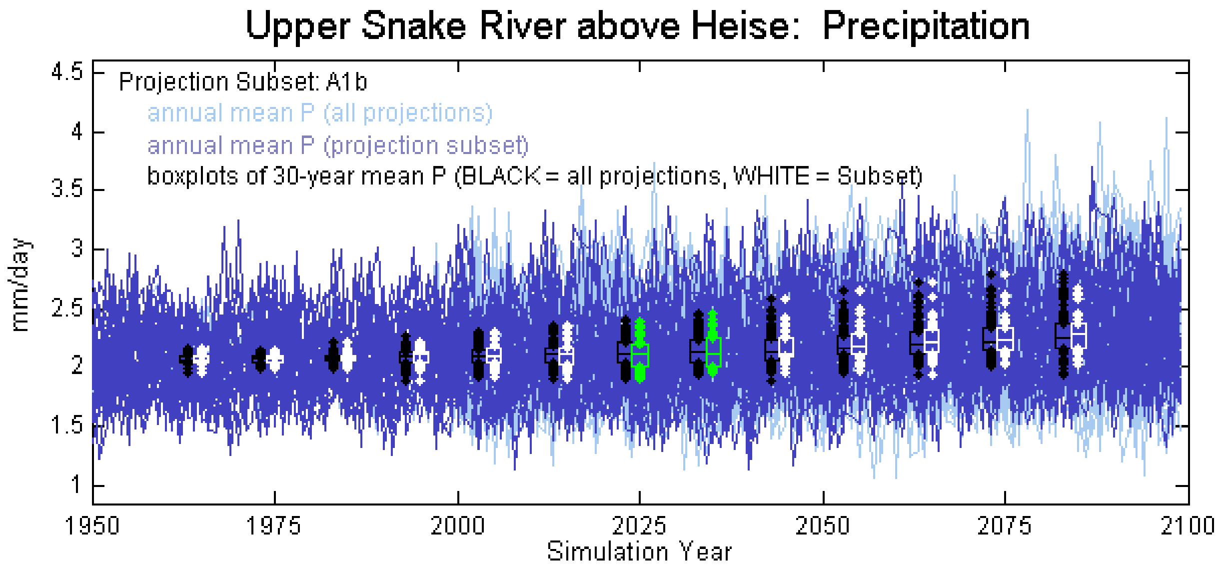
-- basin: *Upper Snake abv Heise*

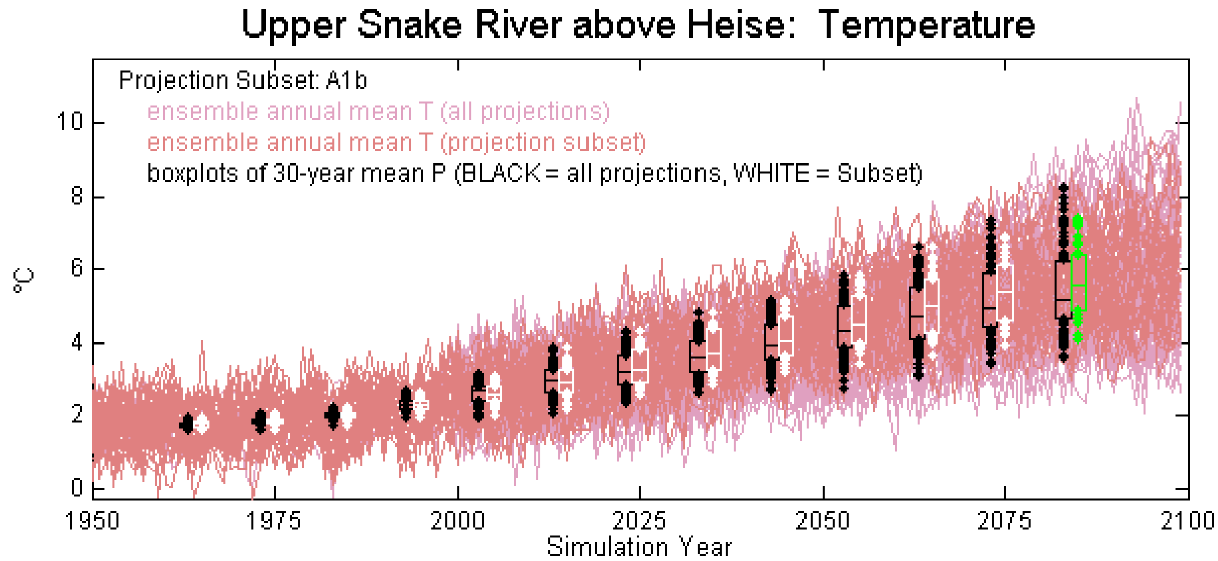
-- annual projections, 1950-2099.

-- boxplots: tracking spread of 30-year, decadally moving

-- black vs white boxplots: All vs A1b

-- green boxplots: periods when All vs A1b showed statistical difference





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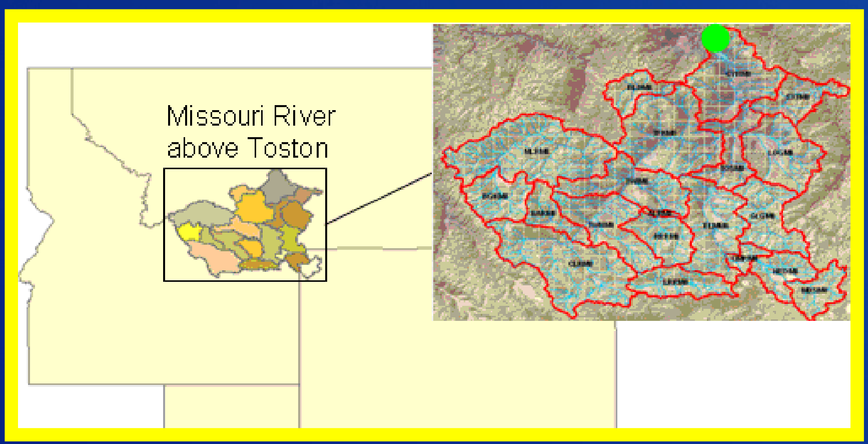
Simulating Basin Hydroclimates:

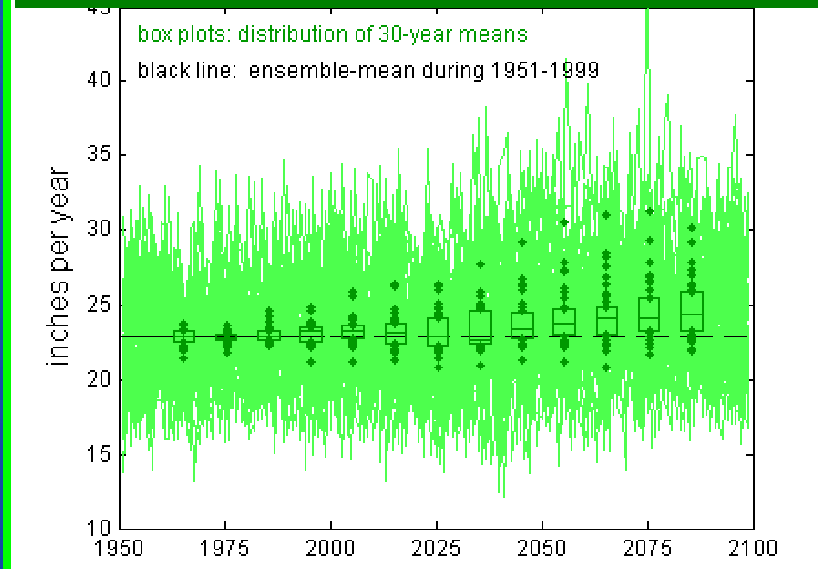
Start with monthly projections of temperature & precipitation over a study basin…

Example*: Upper Missouri, and 39 A1b climate projections.

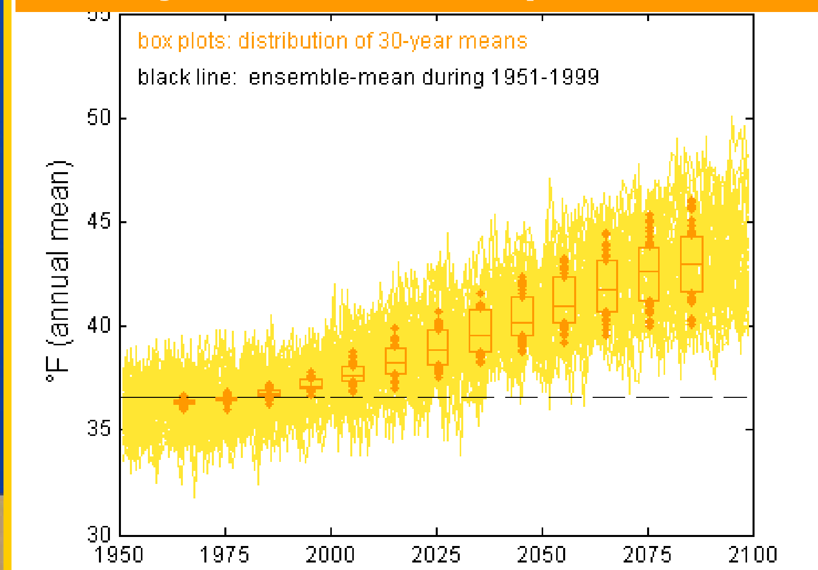


* Reclamation 2008 (DRAFT)

Projected Precipitation

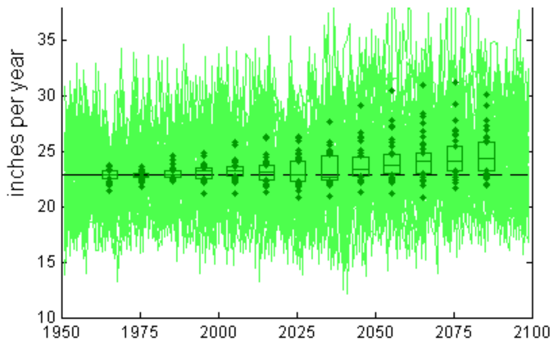


Projected Temperature

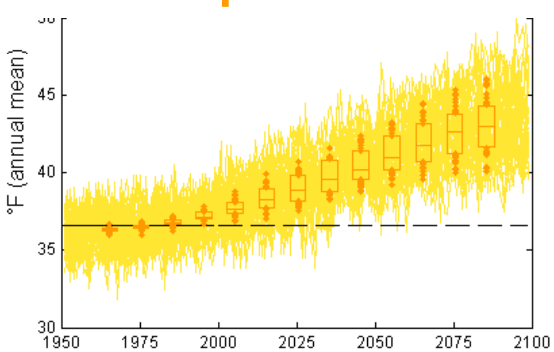


…then translate monthly T and P into sub-monthly inputs for hydrologic modeling… simulate **water balance** projections (runoff, snowpack, etc).

Precipitation



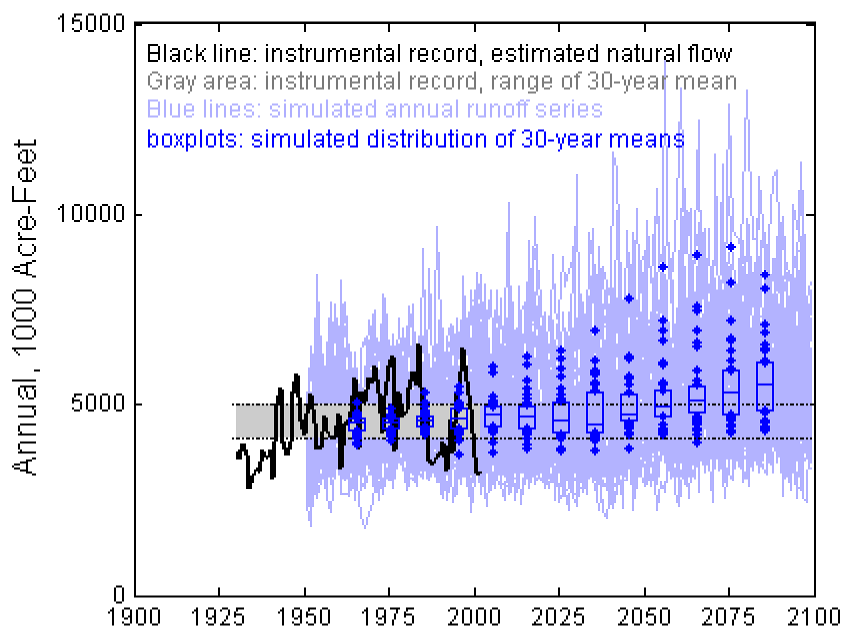
Temperature



Hydrologic Modeling**

Model from NWS MBRFC.

Requires time-disaggregation of archive *monthly* T & P into *six-hourly* T&P (Reclamation 2008).



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Adjusting PET in SacSMA

- RFCs applied SacSMA to our study basins.
- PET is an input to SacSMA.
- These applications were calibrated with the following treatment of PET.
  - mean-monthly PET (climatological PET)
  - cycled annually through calibration years
  - estimation method? varied by RFC, model-developer
- In our study, temperature evolves with time and should be translate into change PET…

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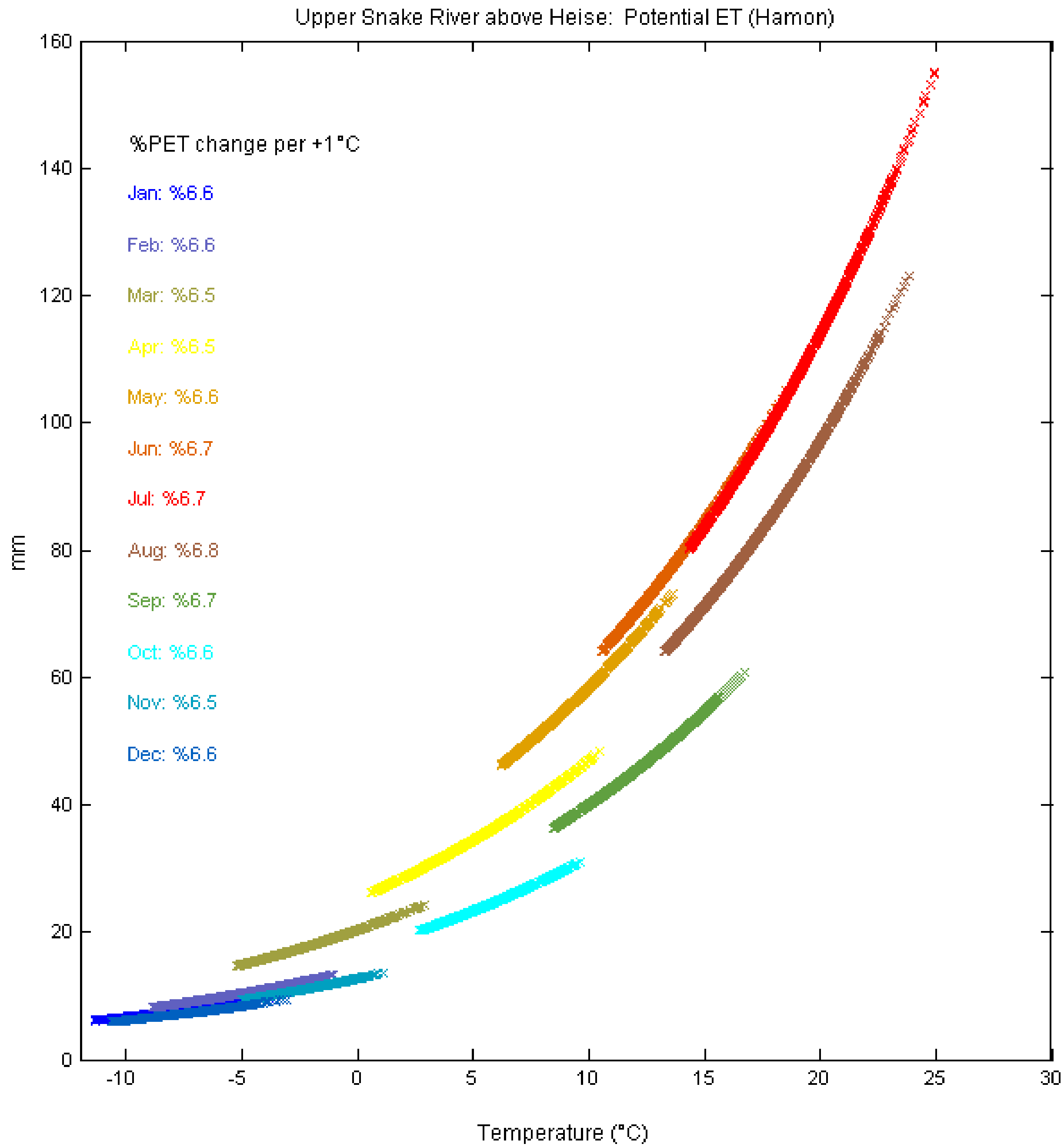
Sensitivity of PET to Temperature Change

Plot shows PET sensitivity to change in T, roughly +6.5% per degC, based on <u>*Hamon*</u> formula.

Clearly, PET is sensitive to warming.

But, different formulas show different sensitivity (e.g., UW NOAH LSM computed PET, using <u>*Penman*</u>, shows roughly +2 to +3% per degC).



Summary

- We're exploring how climate warming might affect water supply predictability and at what rate.

- We're interested in what that implies about forecast portrayal in longer-term planning and forecast usage in contemporary operations.

- We're interested to know whether model-maintenance procedures might be altered through time to preserve predictability.

- Project completion due Sept 2009 (report ~Dec 2009?)

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Questions?

Levi Brekke
Reclamation, Technical Service Center
lbrekke@usbr.gov

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Extras

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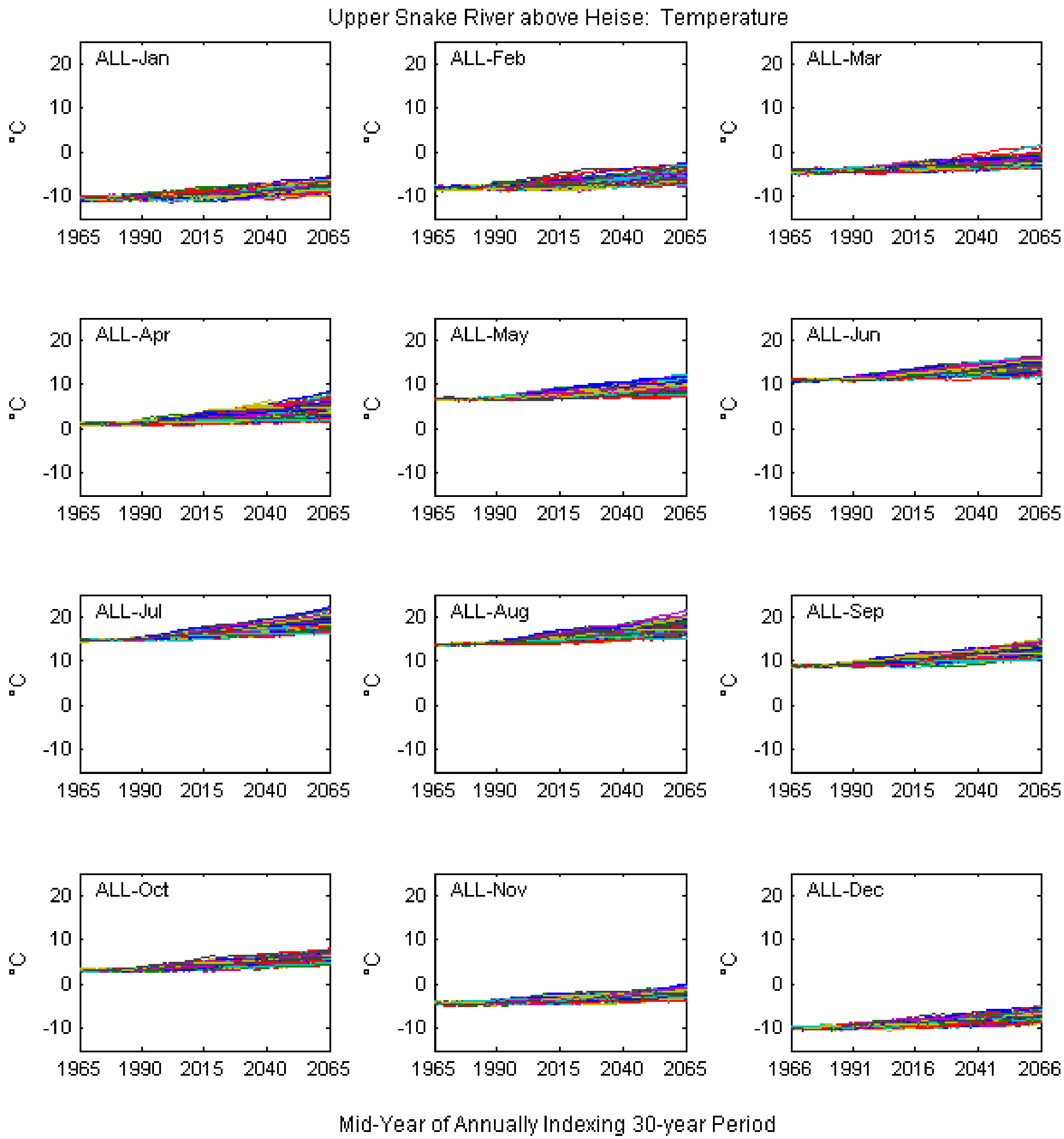
PET Adjustment Scheme

-- Consider one basin-area (*Upper Snake abv Heise*)

-- Consider the collection of climate projections

-- Look at month-specific results

-- Compute month-specific moving 30-year mean T, or *climatological* T (cT), plotted at period centers (x-axis, 1965:1:1985, i.e. 121 periods)

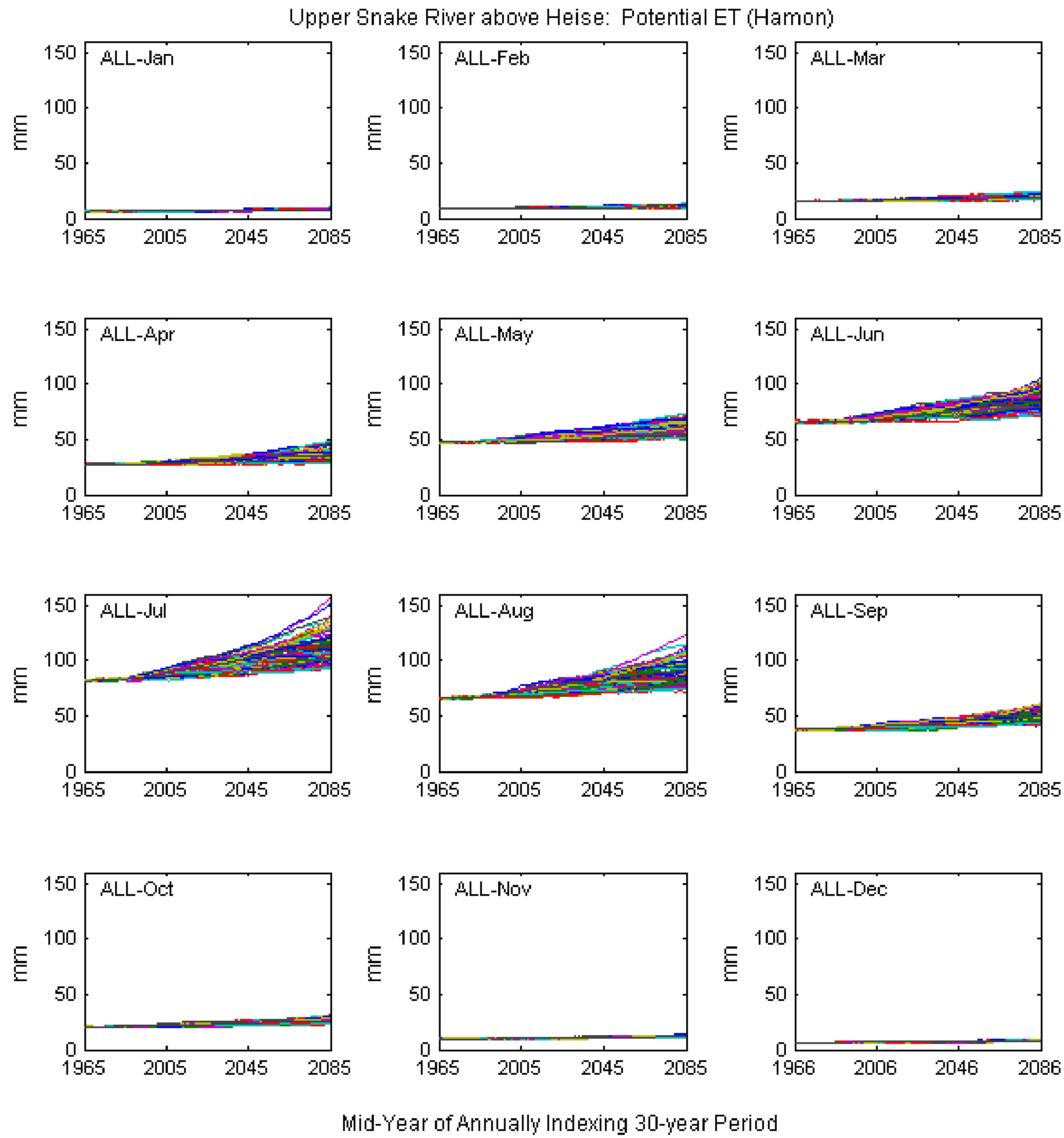


PET Adjustment Scheme

Get formula for PET as function of T (very simplistic! We do this because we do not have projection data to support more complex PET formulas)

e.g., Hamon (1961)

Compute monthly cPET as function of monthly cT, evolving through time – as shown



Hydrology Model

Sacramento Soil Moisture Accounting Model (SAC-SMA)

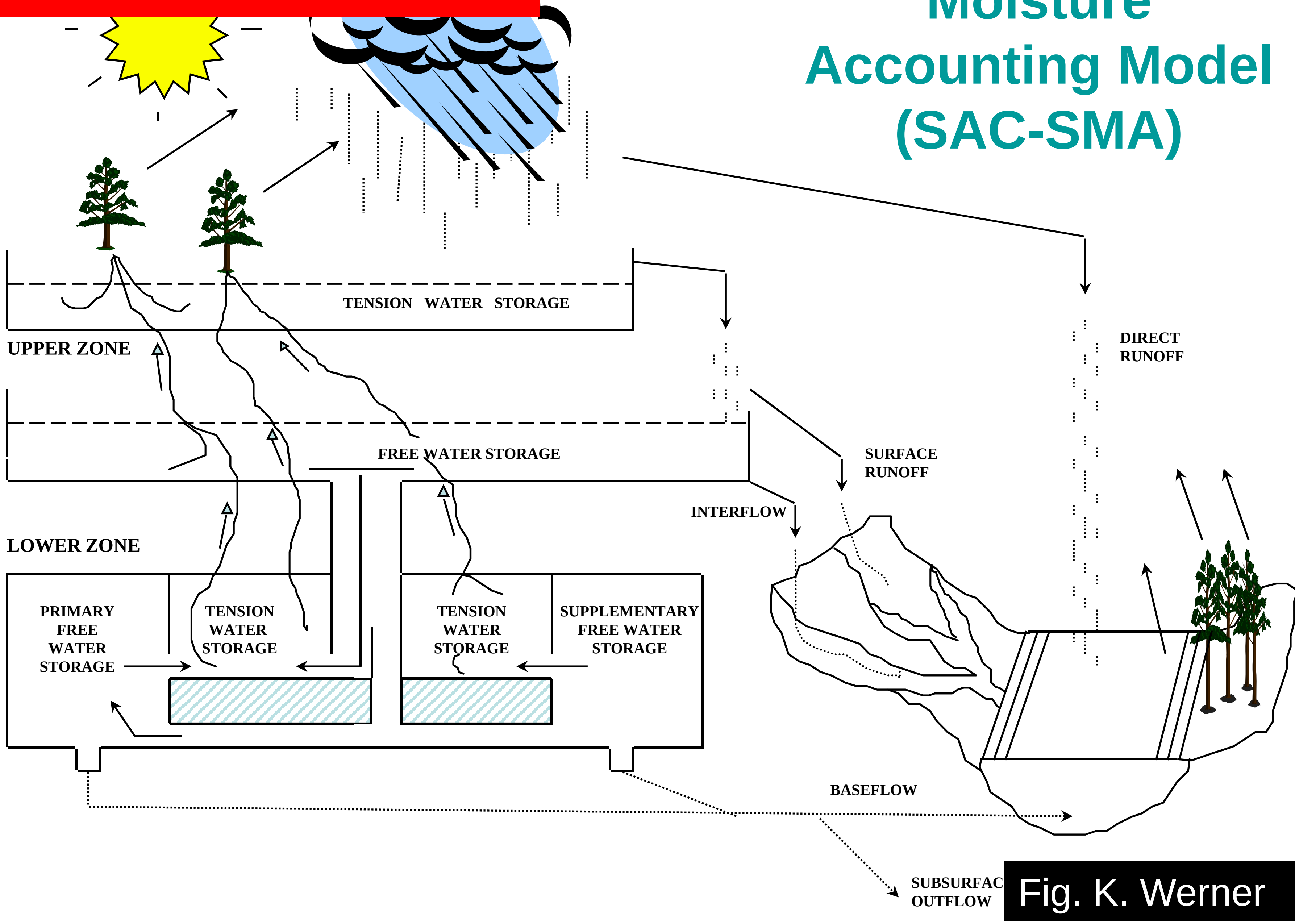


Fig. K. Werner