Implications of Climate Change for Ecological Restoration In the Tahoe Basin

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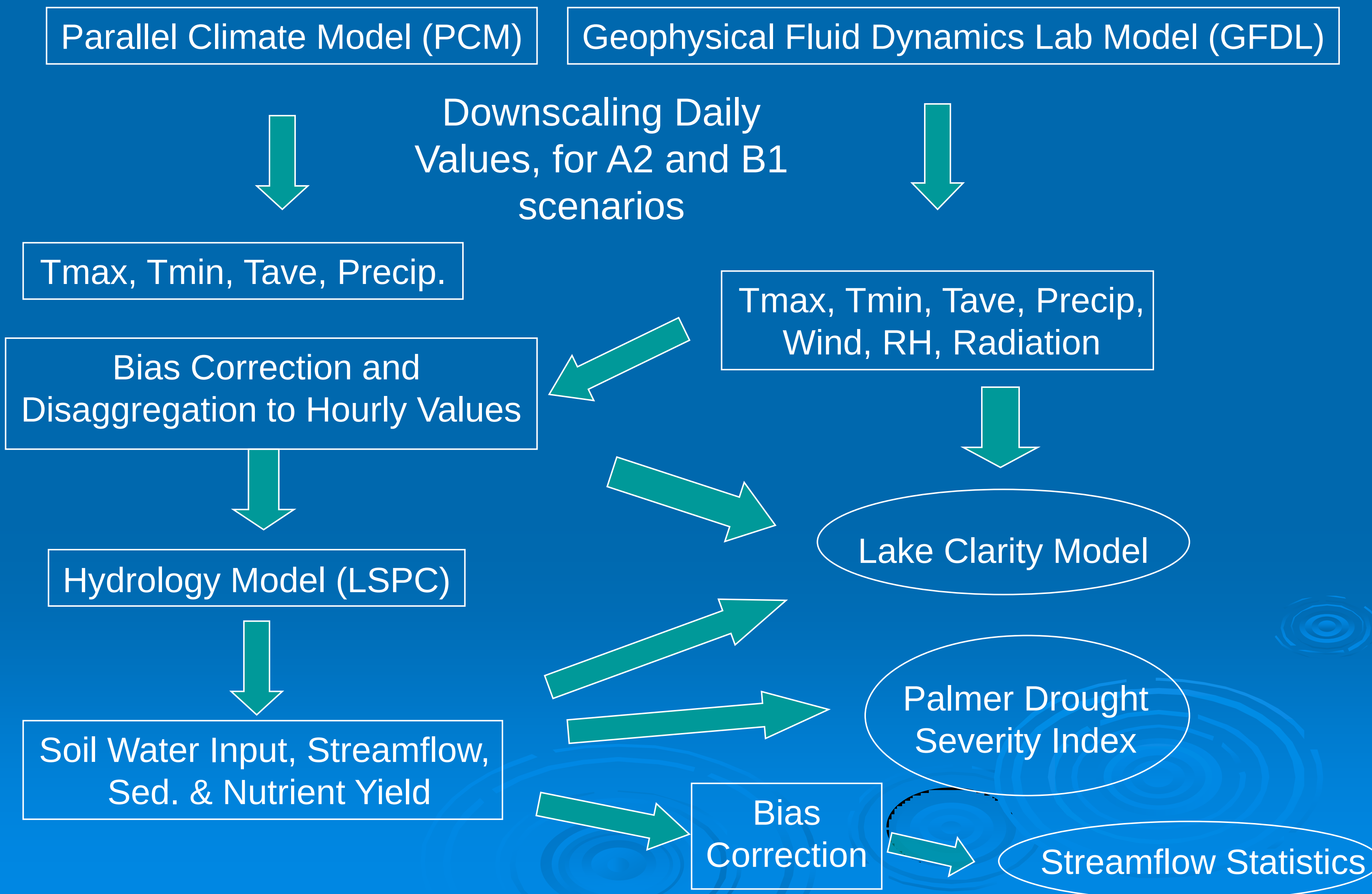
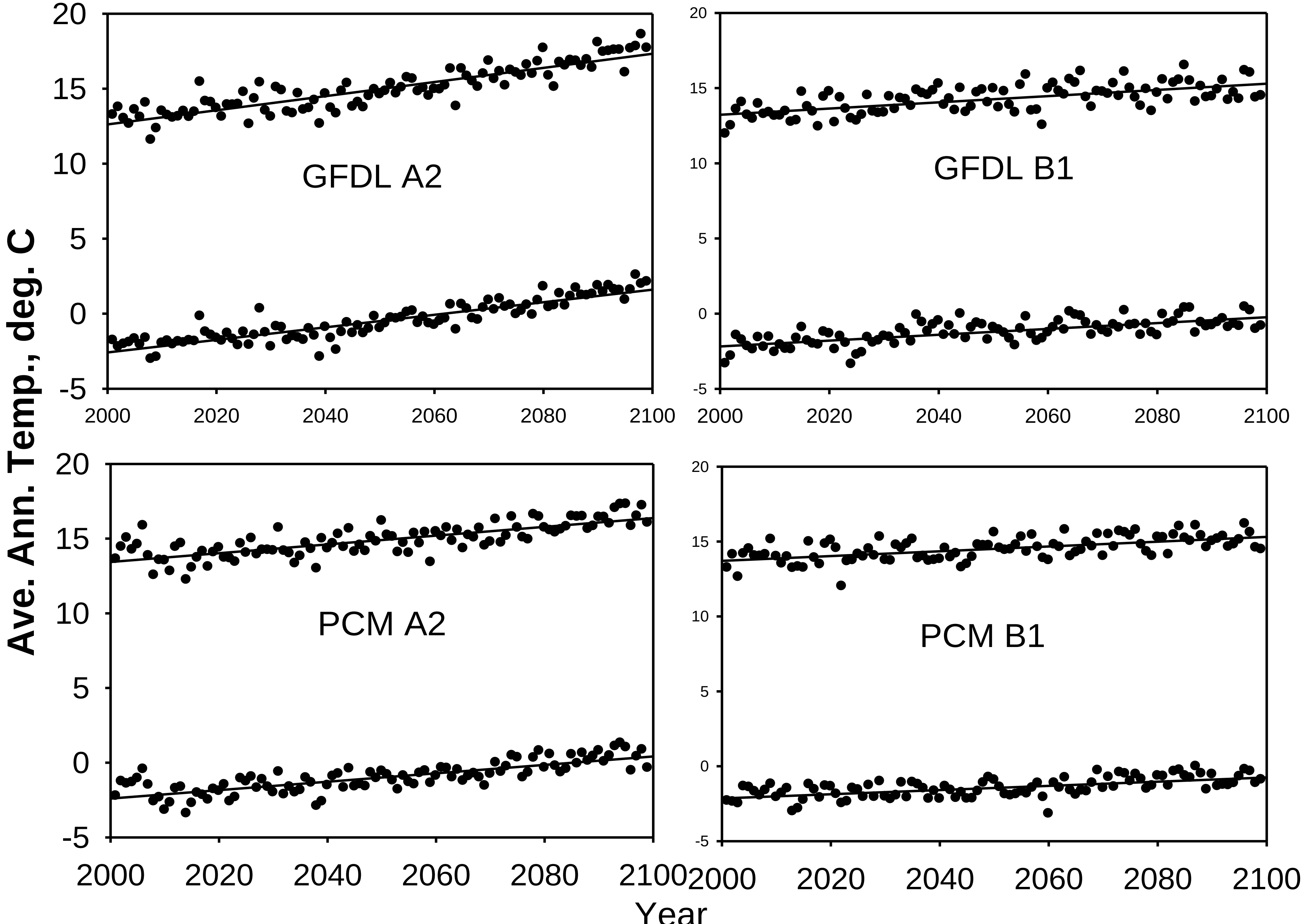
Historic Climate Trends in the Tahoe Basin

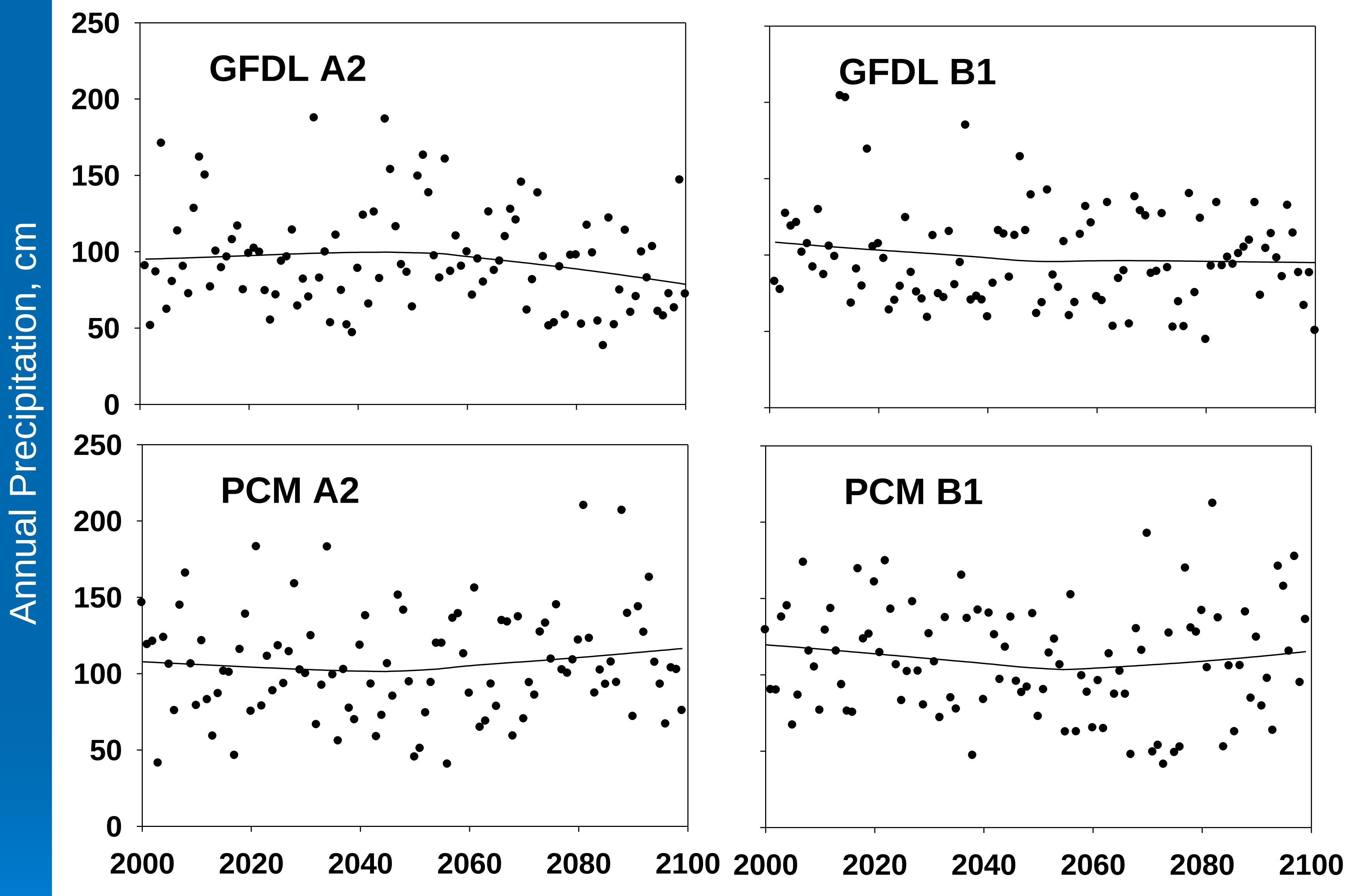
- Upward trend in air temp.; Tmin > Tmax
- Shift from snowfall to rainfall regime
- Increasing intensity of rainfall
- Shift in timing of snowmelt peak ~ 0.4 days/yr
- Warming trends higher than surrounding regions
- Upward trend in ave. lake temp. ~0.013 ^{o}C/yr
- Thermal stability of the lake is increasing

Information Flow for Future Projections



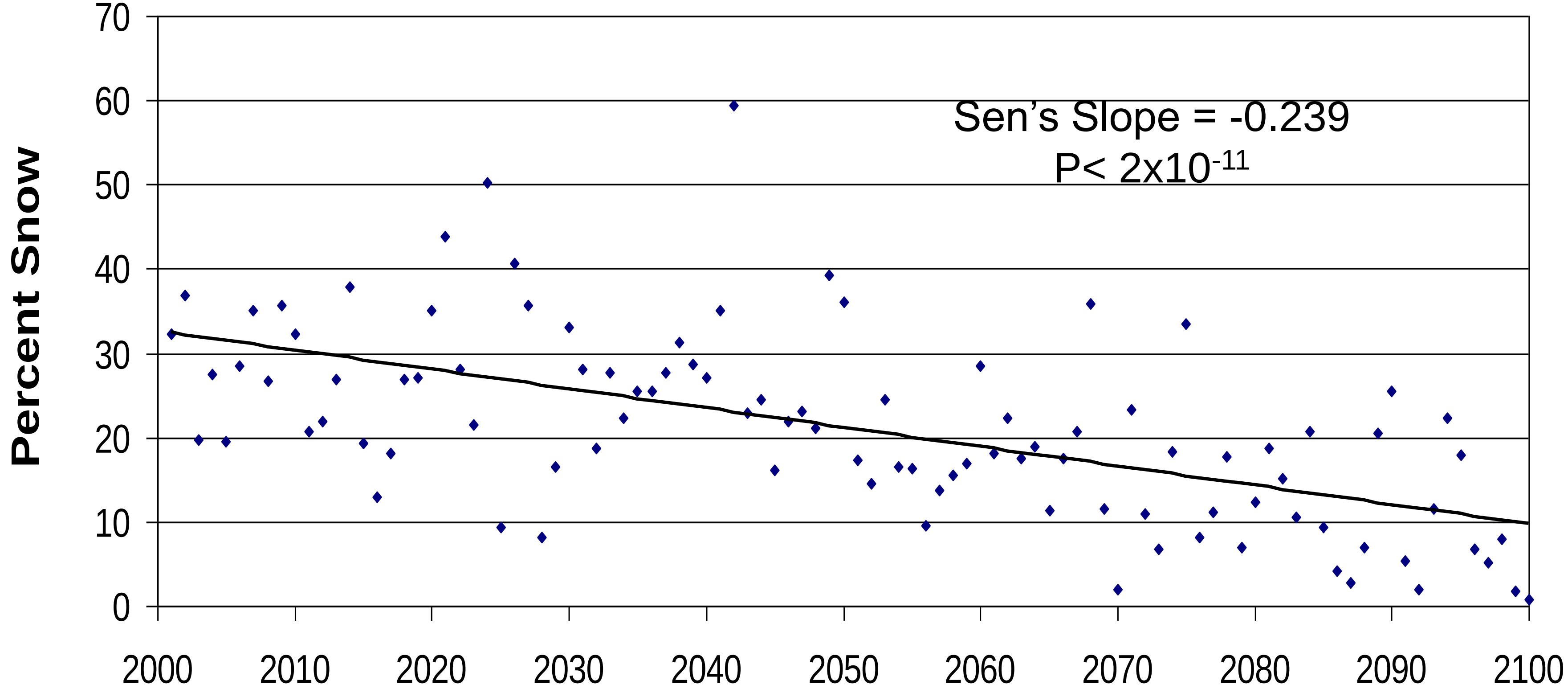


Modeled Trends in Tmax and Tmin, in the Tahoe Basin
Average of 12 Grid Points

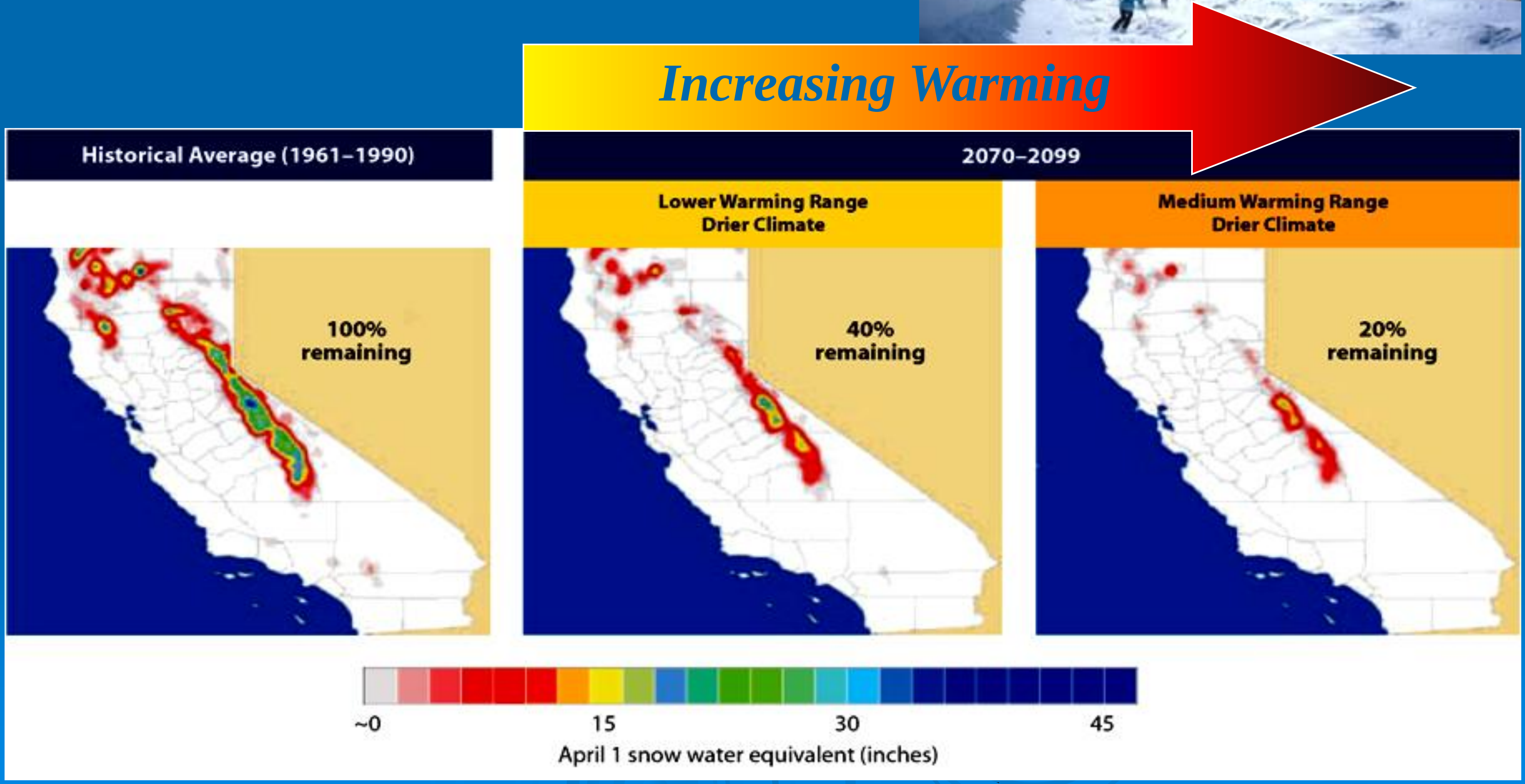


Modeled Precipitation Trends in the Tahoe Basin
Average of 12 Grid Points

GFDL A2 Percent Annual Precipitation as Snow
Tahoe Basin Average



Decreasing Snowpack



CA Climate Change Center Summary Report (2006)

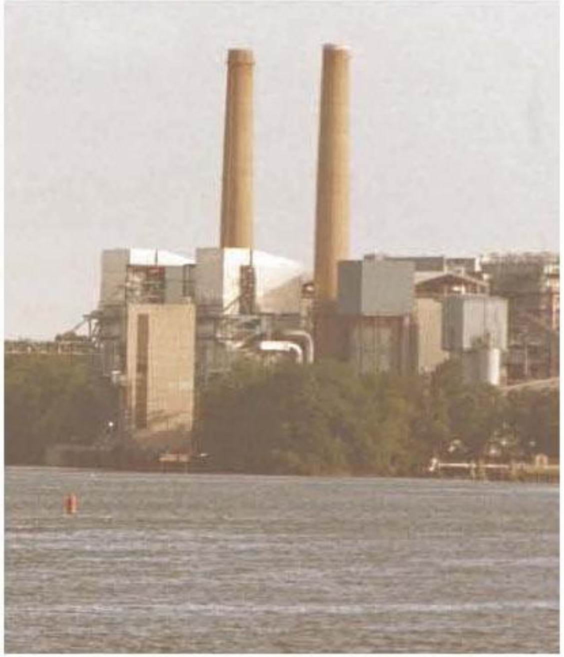
CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year–periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or regional or paleohydrologic data. The pdfs, in turn, are used to evaluate and manage risks to water supplies, waterworks, and floodplains; annual global investment in water infrastructure exceeds U.S.$500 billion (*1*).

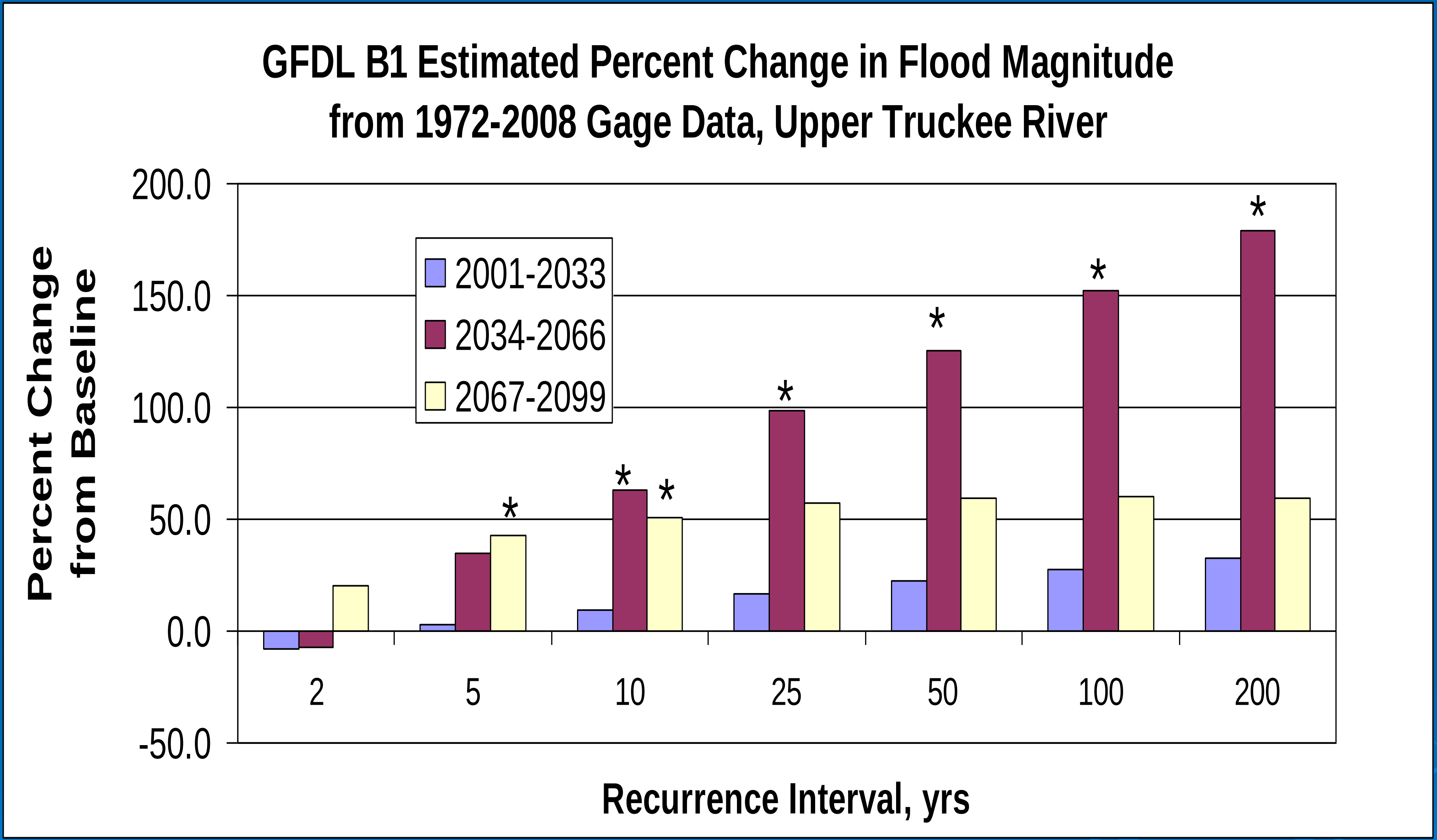


An uncertain future challenges water planners.

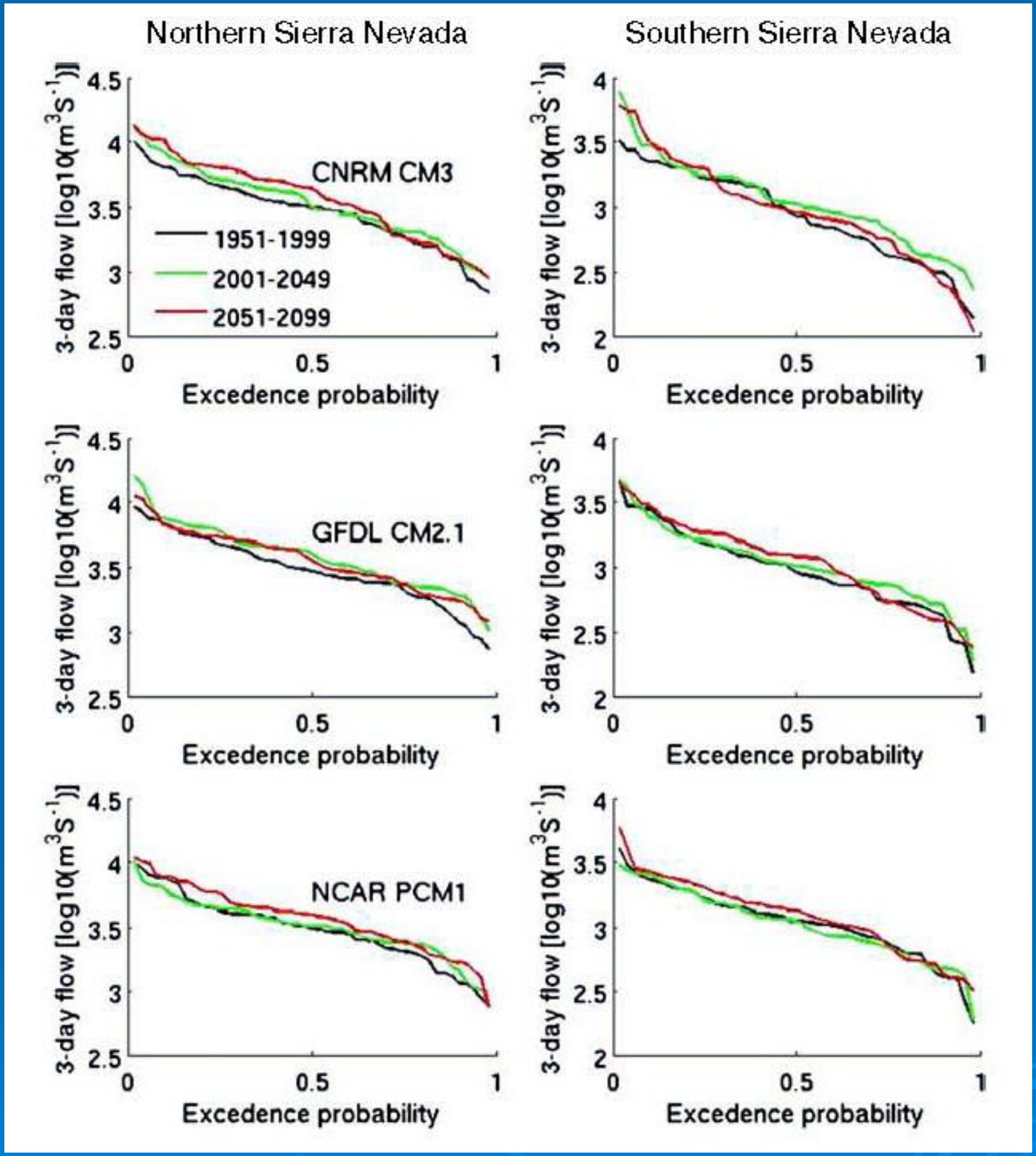
In view of the magnitude and ubiquity of the hydroclimatic change apparently now that has emerged from climate models (see figure, p. 574).

Why now? That anthropogenic climate change affects the water cycle (*9*) and water supply (*10*) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimate had not demonstrably exited the envelope of natural variability and/or the effective range of optimally operated infrastructure (*11*, *12*). Accounting for the substantial uncertainties of climatic parameters estimated from short records (*13*) effectively hedged against small climate changes. Additionally, climate projections were not considered credible (*12*, *14*).

Recent developments have led us to the opinion that the time has come to move beyond the wait-and-see approach. Projections of runoff changes are bolstered by the recently demonstrated retrodictive skill of climate models. The global pattern of observed annual streamflow trends is unlikely to have



* Indicates that change from historic baseline is significant at the 90% level or greater



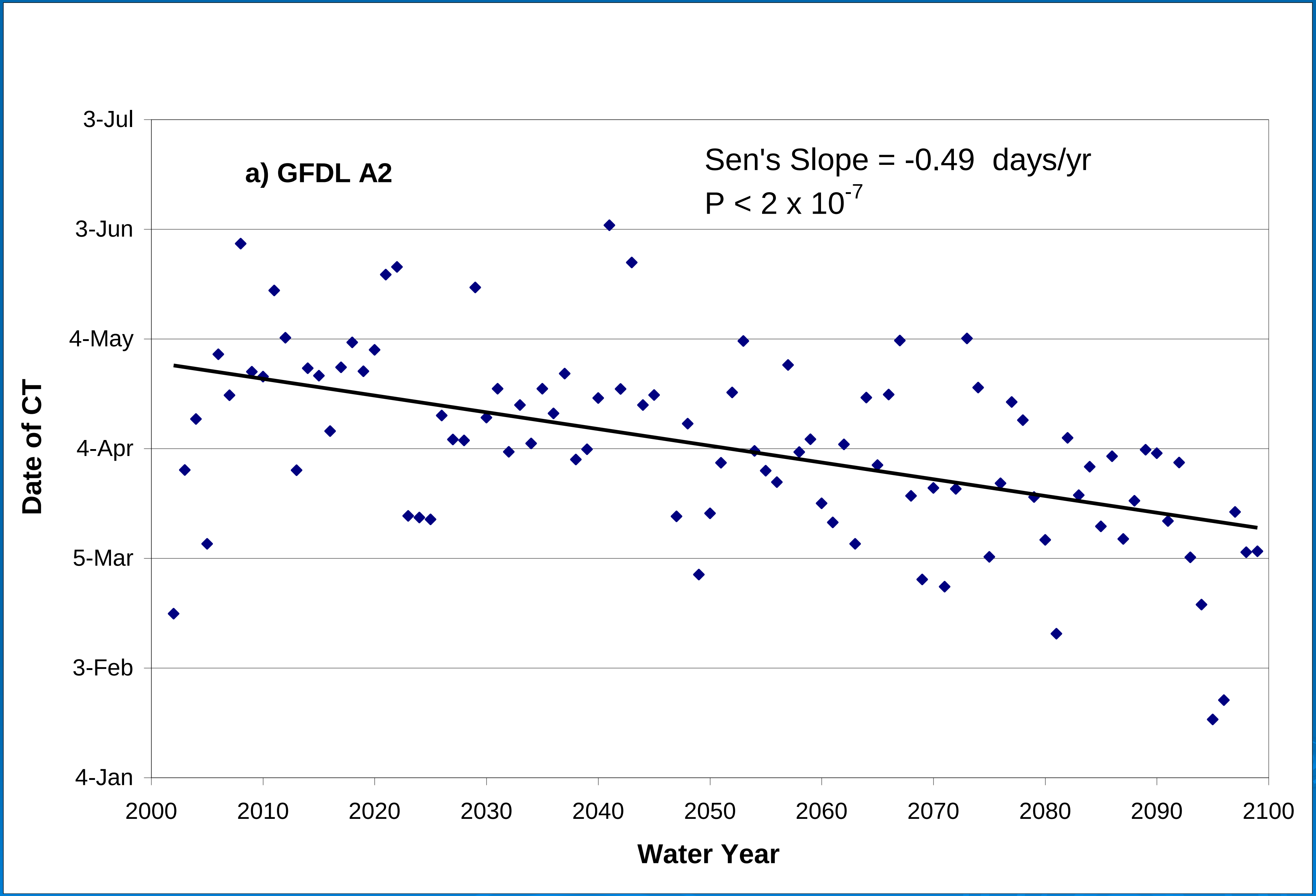
3-days maximum annual streamflows as simulated by downscaled meteorology from from 3 Climate Models

Source: Das et al. 2011. Climatic Change 109 Suppl. 1: 77-94

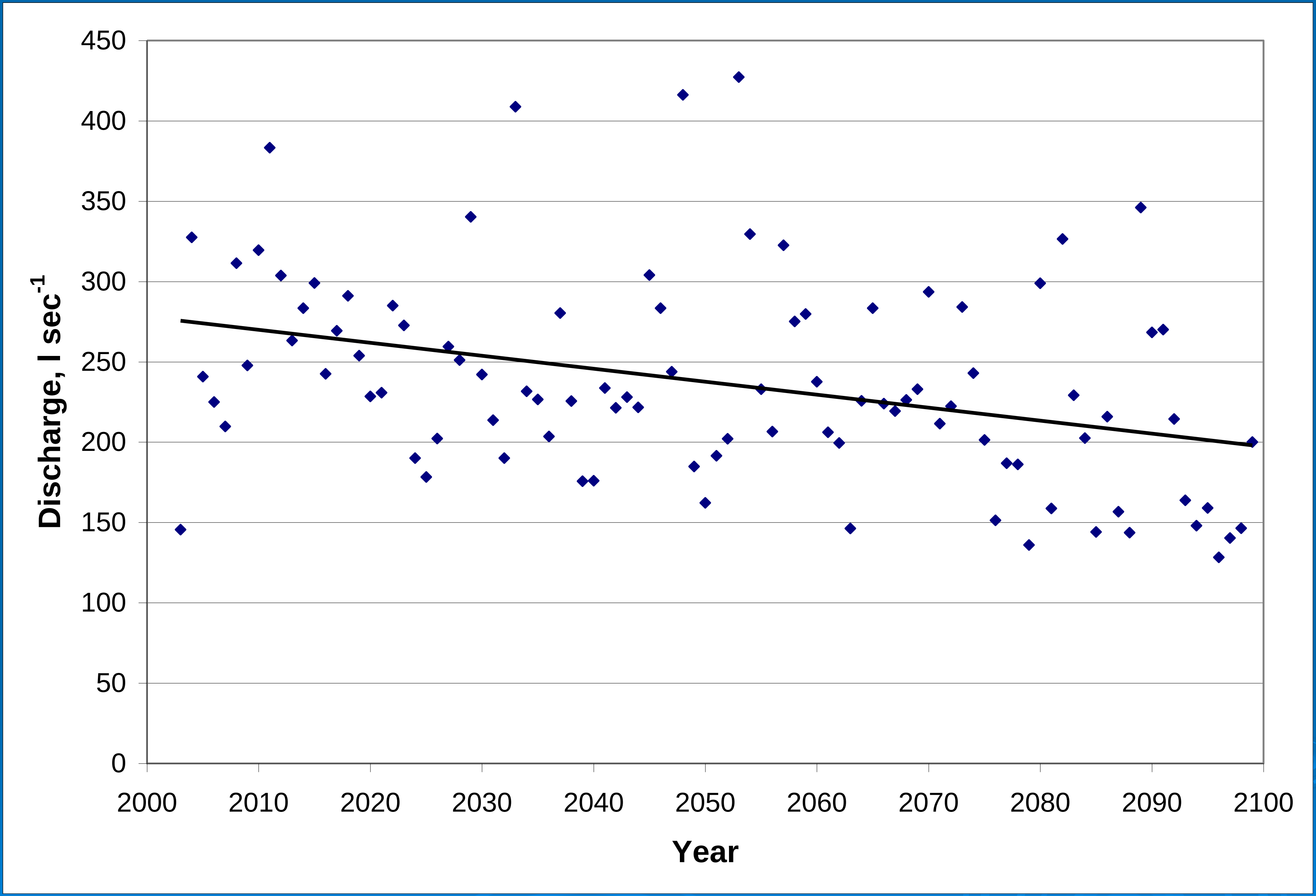
Photo by Scott Hackley

Ward Creek, December 31, 2005

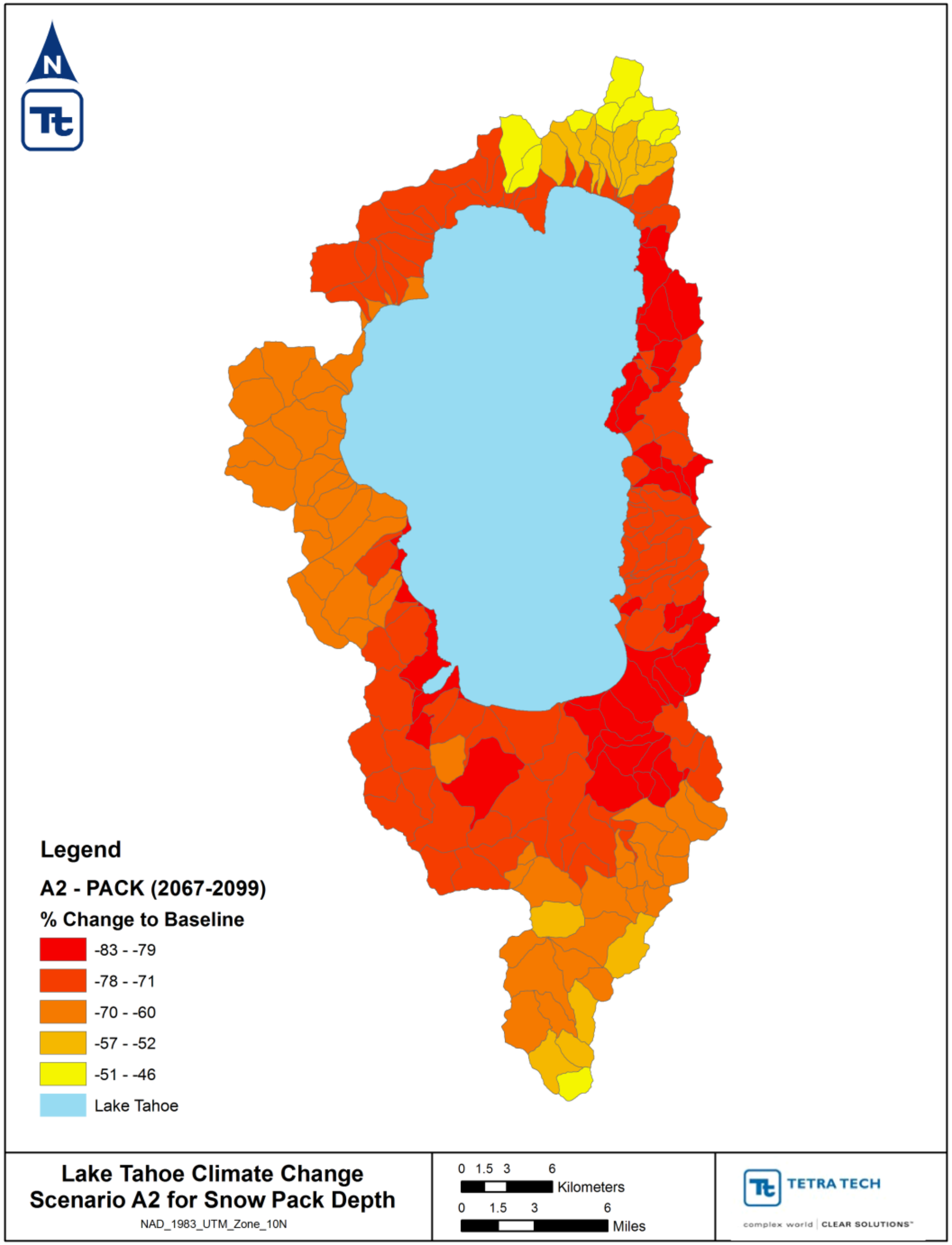
Impacts of the 1997 flood, Lower Ward Creek, Oct. 2005



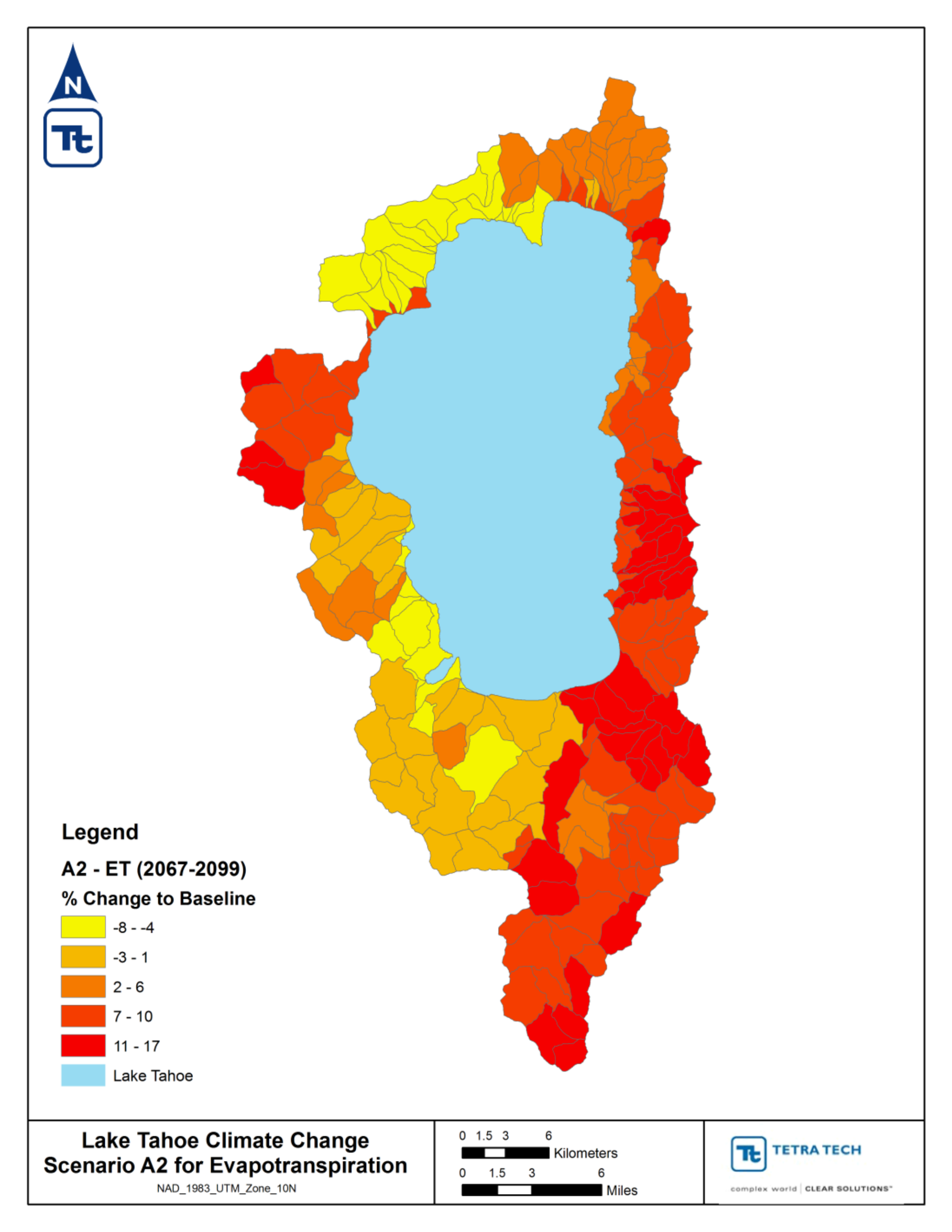
Shift of Snowmelt (ann. hydrograph centroid) toward earlier dates, Upper Truckee River



Upper Truckee River 5-day min. discharge, GFDL A2

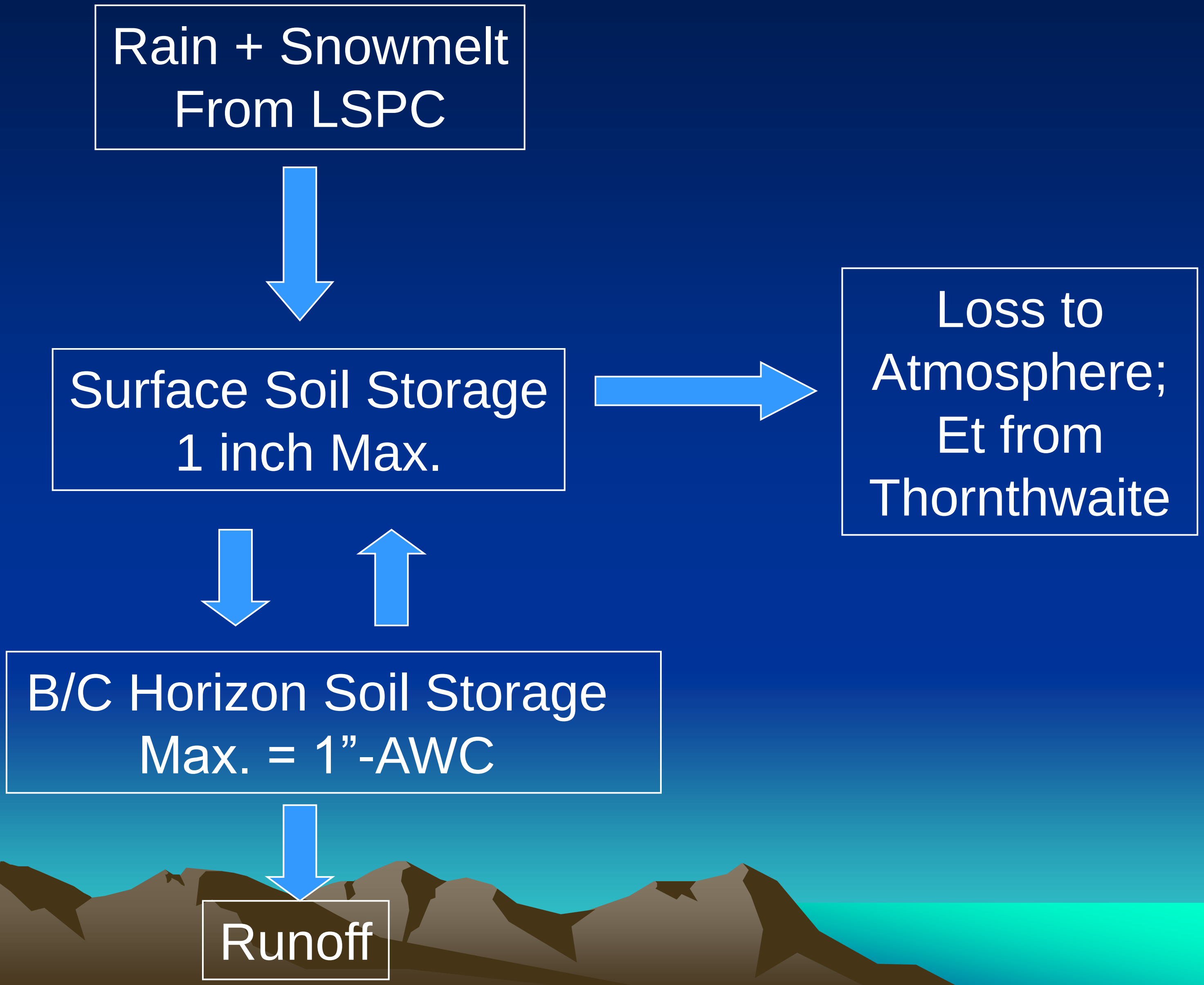


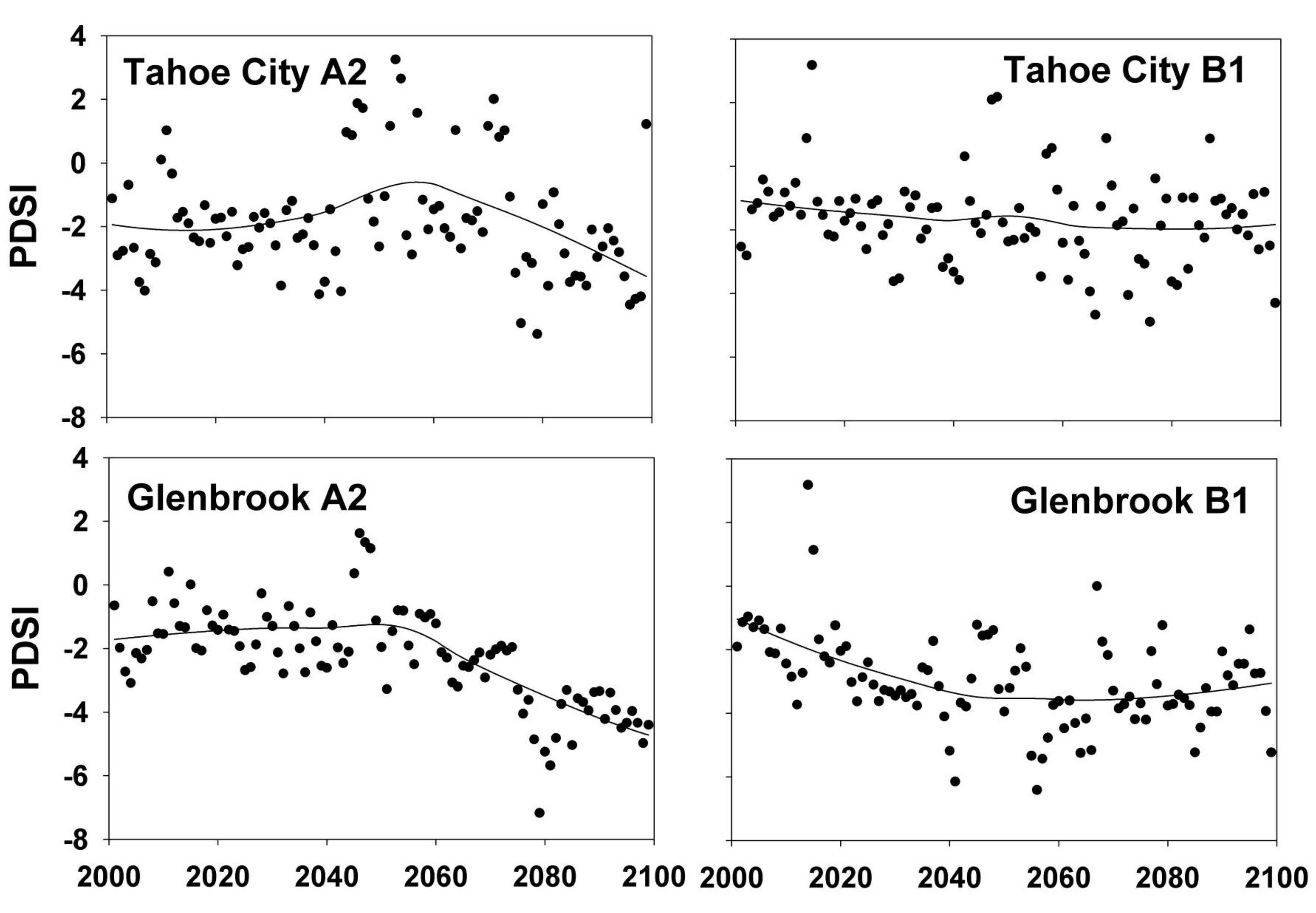
Spatial variation of snowpack depth for GFDL A2 scenario (2067-2099).



Spatial variation of evapotranspiration (ET) for GFDL A2 (2067-2099).

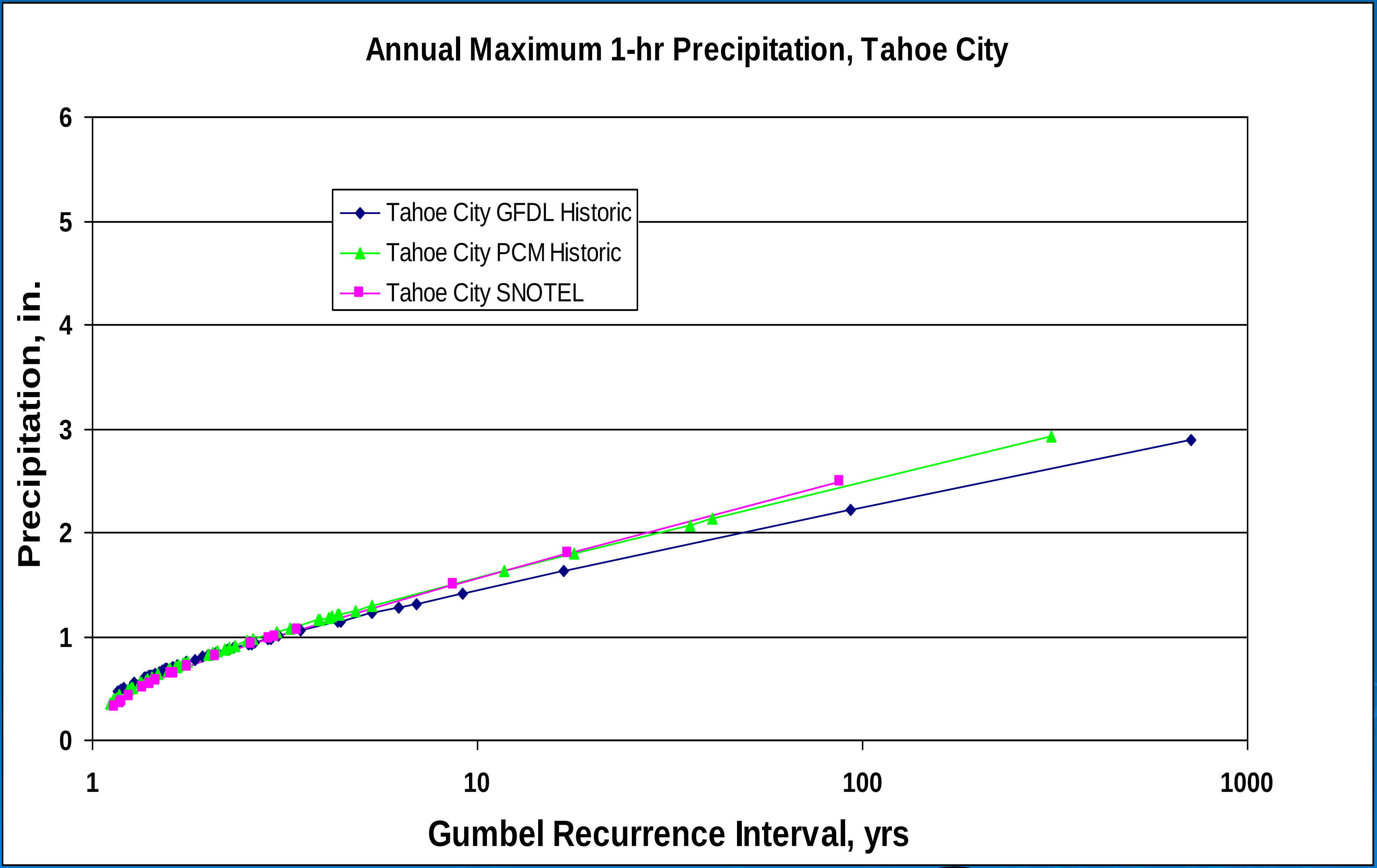
The Palmer Drought Severity Index

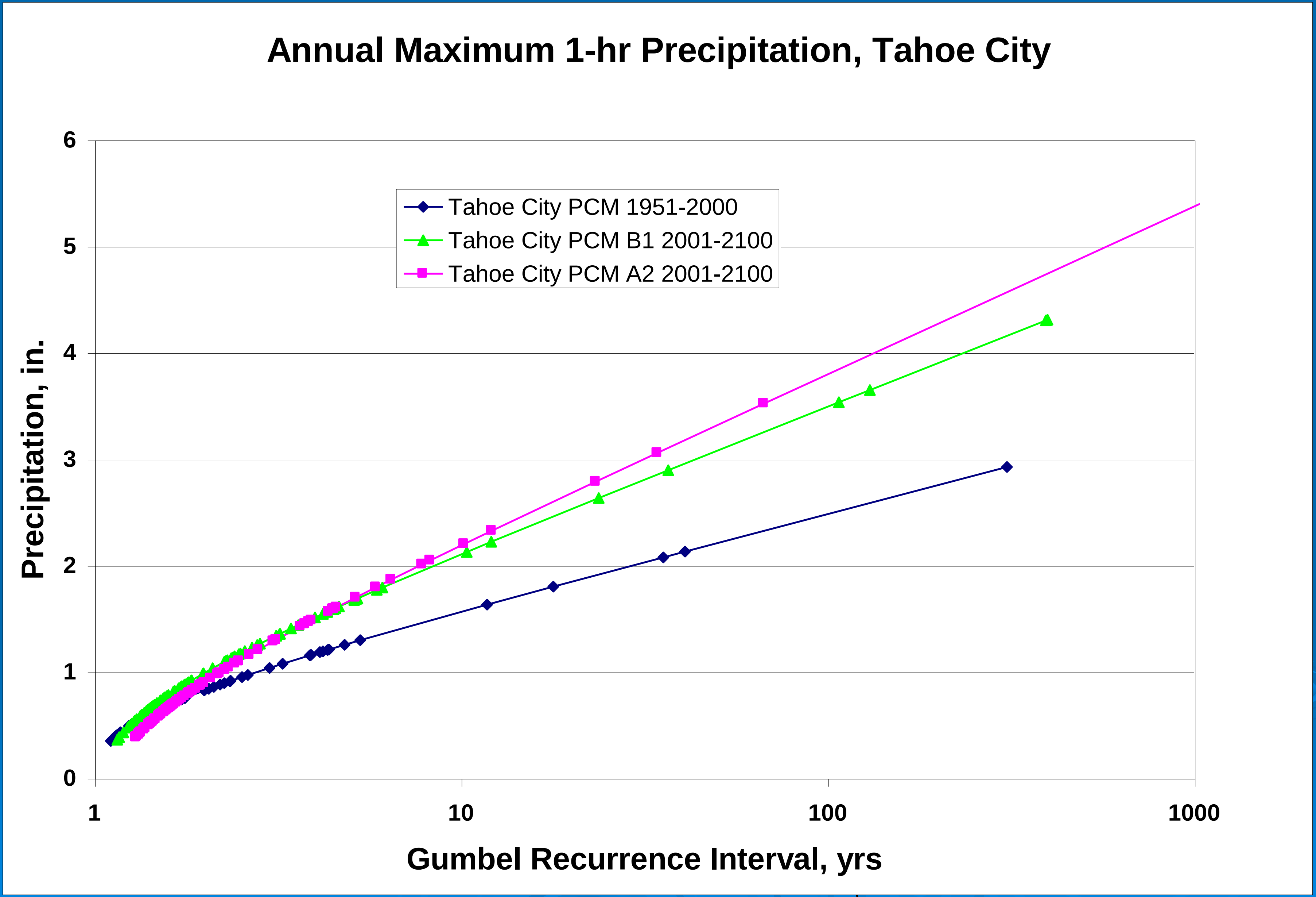




Modeled Annual Minimum Weekly Palmer Drought Severity Index at 2 stations for 2 scenarios in the Tahoe basin




Annual Maximum 1-hr Precipitation, Tahoe City
Tahoe City GFDL Historic
Tahoe City PCM Historic
Tahoe City SNOTEL
Precipitation, in.
0
1
2
3
4
5
6
1
10
100
1000
Gumbel Recurrence Interval, yrs



Annual Maximum 1-hr Precipitation, Tahoe City
Tahoe City PCM 1951-2000
Tahoe City PCM B1 2001-2100
Tahoe City PCM A2 2001-2100
Precipitation, in.
Gumbel Recurrence Interval, yrs
0
1
2
3
4
5
6
1
10
100
1000

ECOLOGY

Assisted Colonization and Rapid Climate Change

Moving species outside their historic ranges may mitigate loss of biodiversity in the face of global climate change.

O. Hoegh-Guldberg,[1]* L. Hughes,[2] S. McIntyre,[3] D. B. Lindenmayer,[4] C. Parmesan,[5] H. P. Possingham,[6] C. D. Thomas[7]

Rapid climatic change has already caused changes to the distributions of many plants and animals, leading to severe range contractions and the extinction of some species (*1*, *2*). The geographic ranges of many species are moving toward the poles or to higher altitudes in response to shifts in the habitats to which these species have adapted over relatively longer periods (*1*–*4*). It already appears that some species are unable to disperse or adapt fast enough to keep up with the high rates of climate change (*5*, *6*). These organisms face increased extinction risk, and, as a result, whole ecosystems, such as cloud forests and coral reefs, may cease to function in their current form (*7*–*9*).

Current conservation practices may not be enough to avert species losses in the face of mid- to upper-level climate projections (>3°C) (*10*), because the extensive clearing and destruction of natural habitats by humans disrupts processes that underpin species dispersal and establishment. Therefore, resource managers and policy-makers must contemplate moving species to sites where they do not currently occur or have not been known to occur in recent history. This strategy flies in the face ately moving species are regarded with suspicion. Our contrary view is that an increased understanding of the habitat requirements and distributions of some species allows us to identify low-risk situations where the benefits of such "assisted colonization" can be realized and adverse outcomes minimized.

Previous discussions of conservation responses to climate change have considered assisted colonization as an option (*11*, *12*), but have stopped short of providing a risk assessment and management framework for how to proceed. Such frameworks could assist in identifying circumstances that require moderate action, such as enhancement of conventional conservation measures, or those that require more extreme action, such as assisted colonization. These frameworks need to be robust to a range of uncertain futures (*13*). Uncertainties arise in climate projections and in how species and ecosystems will respond. Hence, calculation of the lower and upper bounds for the probability and cost of a range of possible outcomes may be the best strategy.

With this in mind, we developed a decision framework that can be used to outline potential actions under a suite of possible future climate scenarios (see figure, below). Determining whether a species faces significant risk of decline or extinction under climate change requires an in-depth knowledge of the underlying species' biology as well as the biological, physical, and chemical changes occurring within its environment. The risk of extinction for many widespread, generalist species found across a range of habitats may be low. In this case, the option of moving such species outside their present

2008. Science 321:345

Photo from LTSLT

Tahoe yellow cress (*Rorippa subumbellata*)


PLEASE DO NOT ENTER
RARE AND ENDANGERED, PLANT HABITAT
TAHOE YELLOW CRESS
IT GROWS ON A FEW SANDY BEACHES AROUND
LAKE TAHOE – AND NOWHERE ELSE IN THE WORLD.
UNFORTUNATELY, NEARLY ALL THESE TINY PLANTS
HAVE BEEN ELIMINATED BY MAN'S ACTIVITIES
AROUND TAHOE'S SHORELINE.
INSIDE THIS FENCE IS A SMALL COLONY
OF THESE PLANTS.
PLEASE HELP US PRESERVE IT
BY STAYING OUTSIDE THE FENCED AREA.
THANK YOU.
NATIONAL FOREST LANDS
LAKE TAHOE BASIN


PLEASE DO NOT ENTER
RARE AND ENDANGERED PLANT HABITAT
TAHOE YELLOW CRESS (Rorippa subumbellata)
IS A SMALL MEMBER OF THE MUSTARD FAMILY...
...IT GROWS ON A FEW SANDY BEACHES AROUND
LAKE TAHOE – AND NOWHERE ELSE IN THE WORLD.
UNFORTUNATELY, NEARLY ALL THESE TINY PLANTS
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FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE
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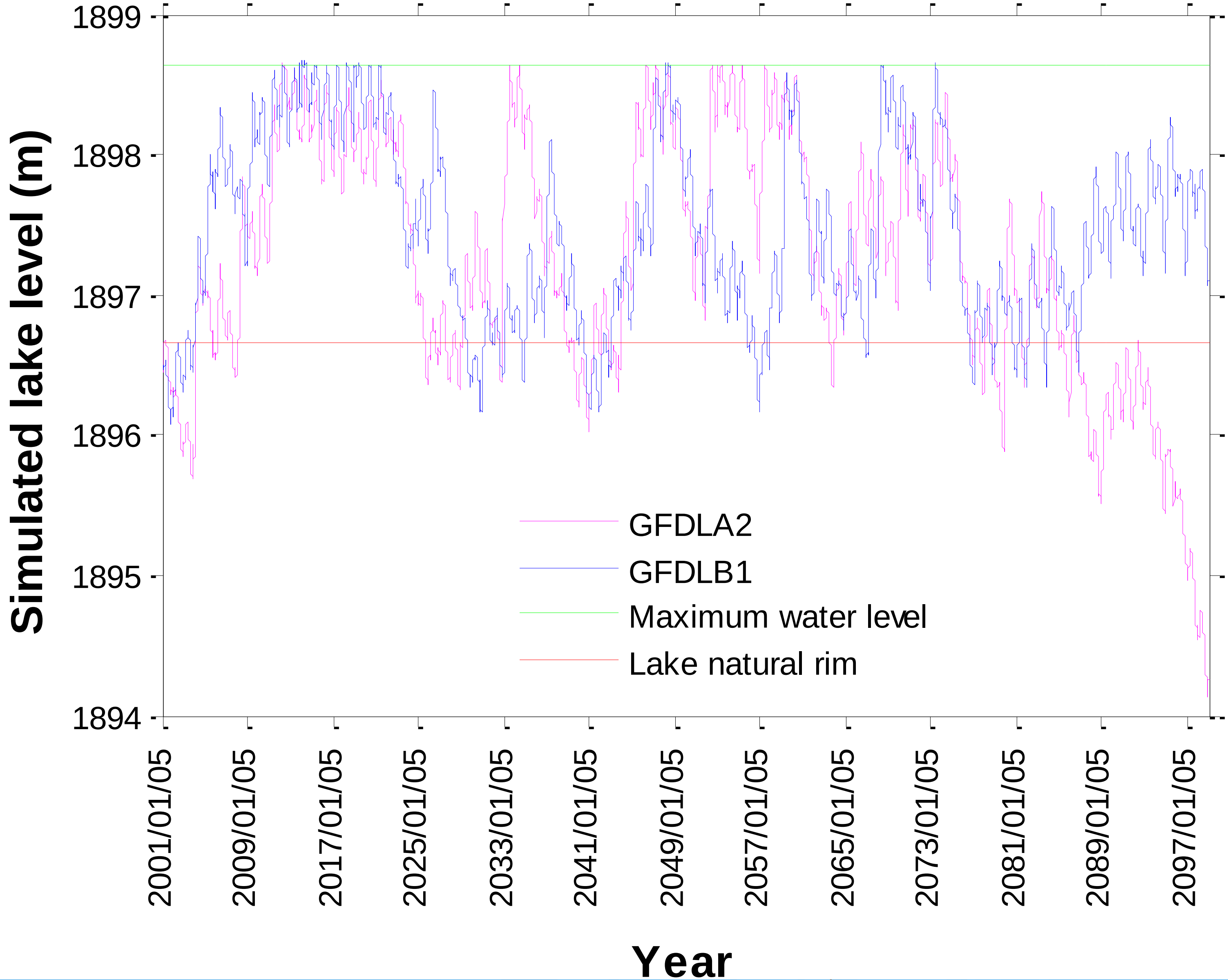
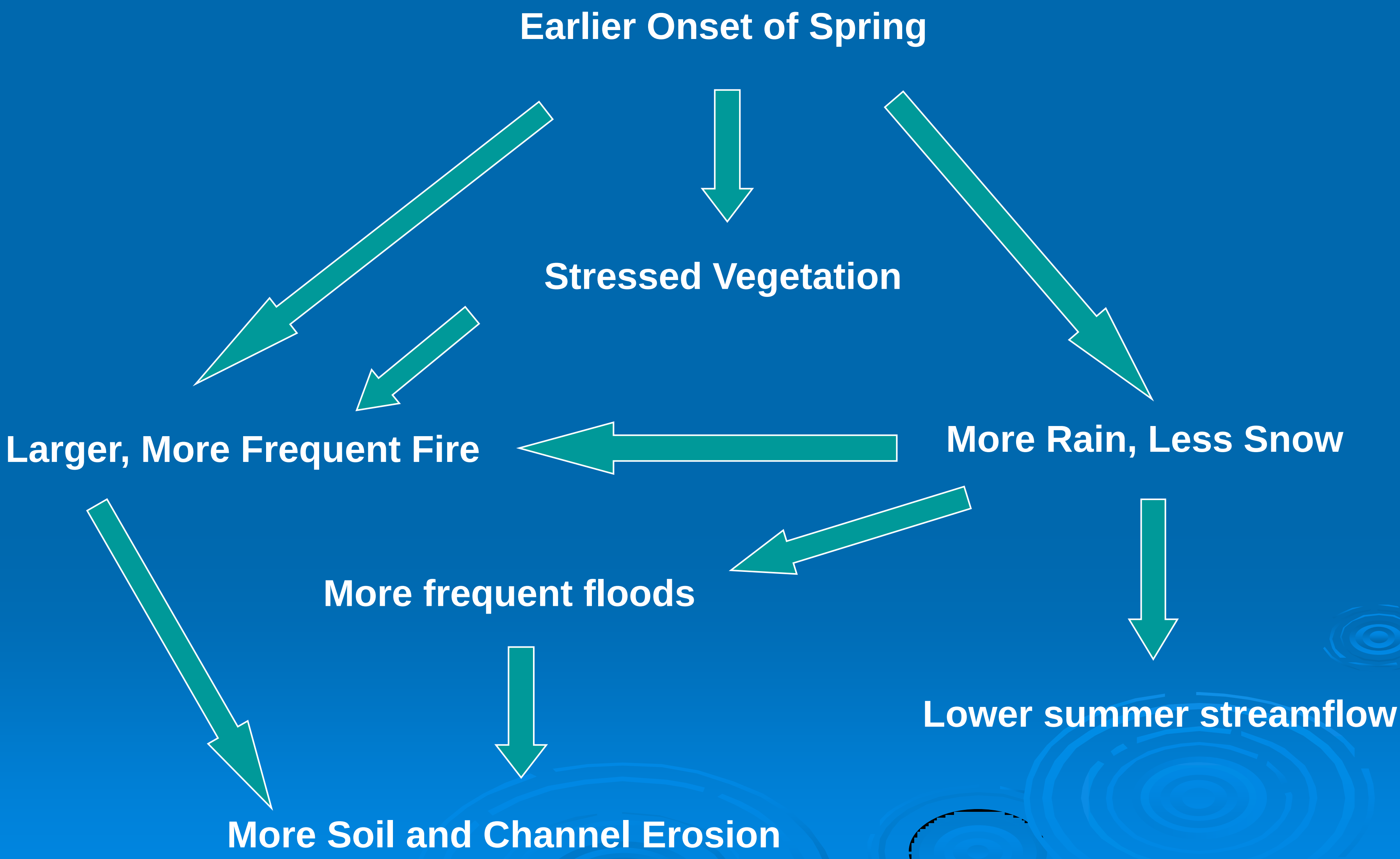
LAKE TAHOE BASIN

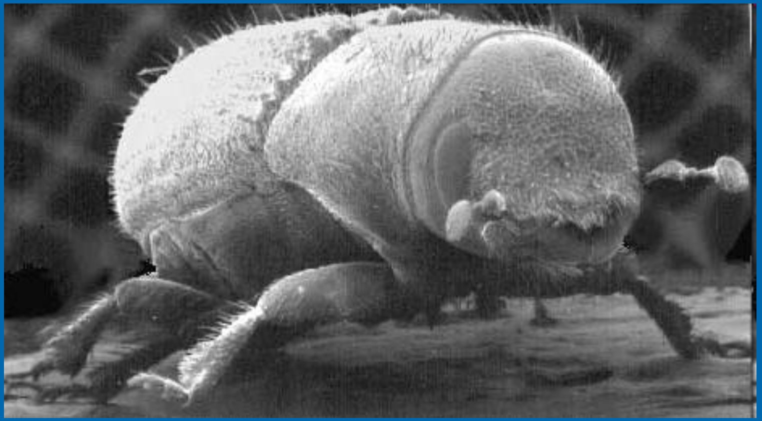


From: Sahoo et al. 2012 Climatic Change *in press*

Changes in the Watershed

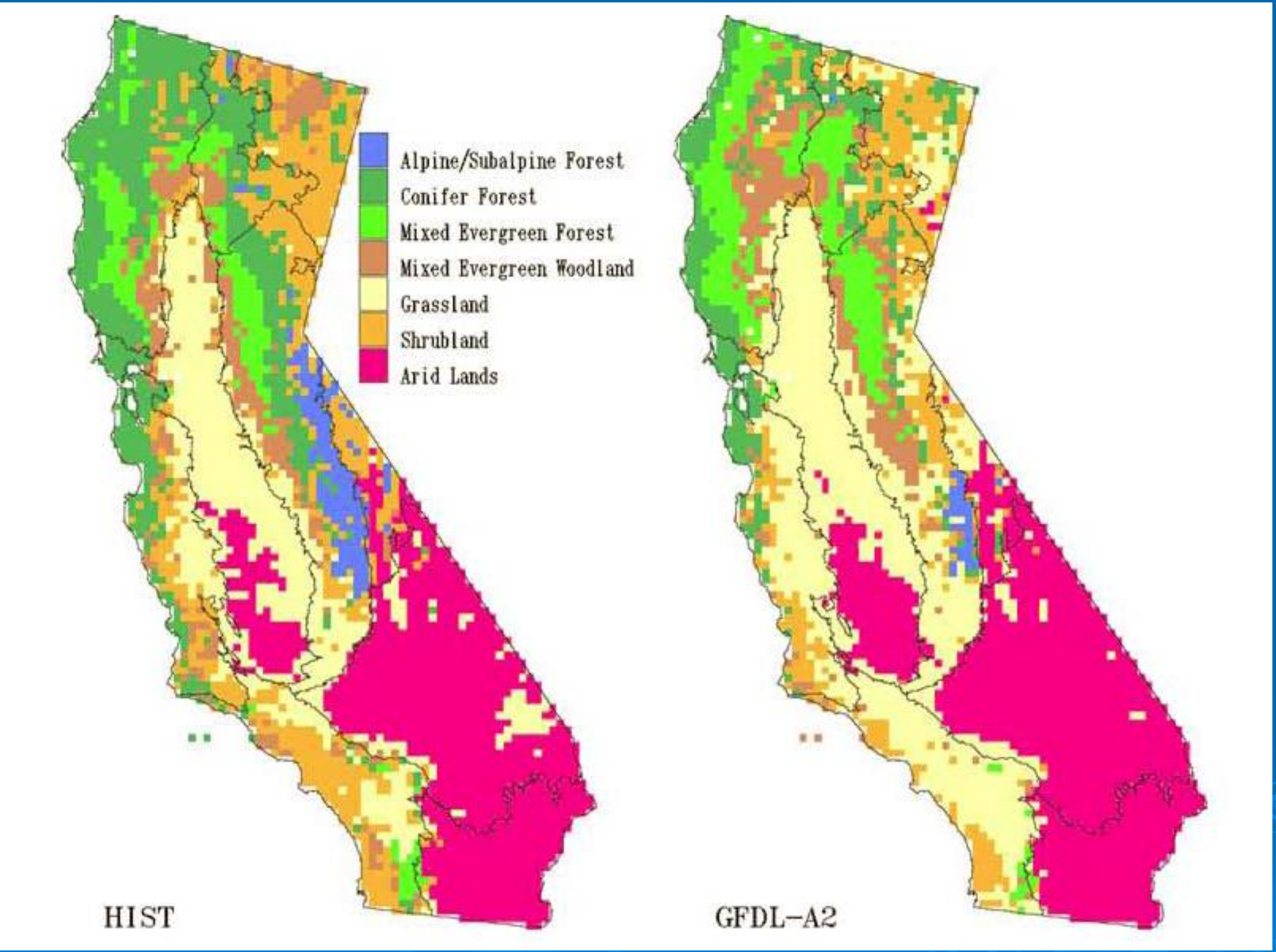


Pinus monticola

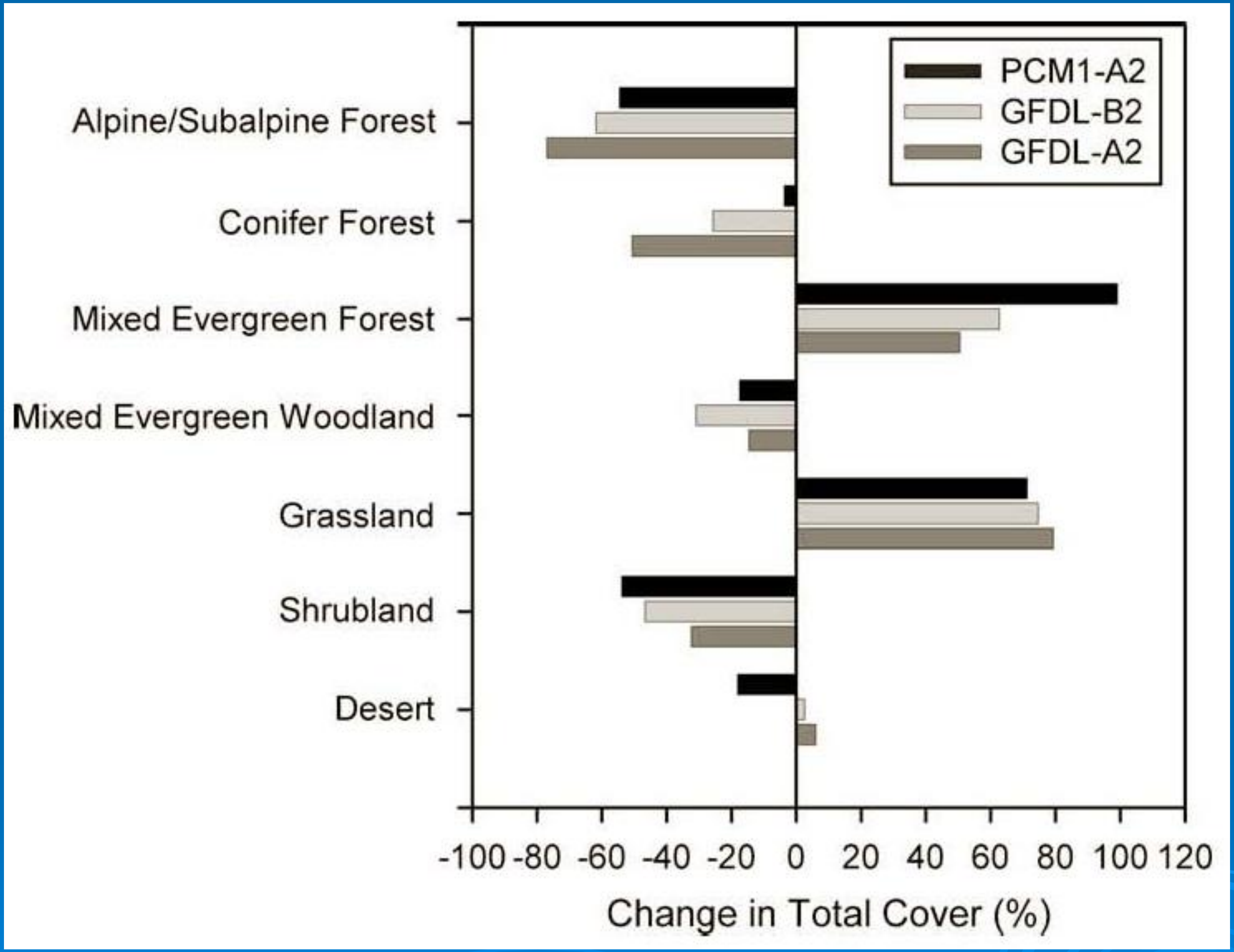


Dendroctonus ponderosae

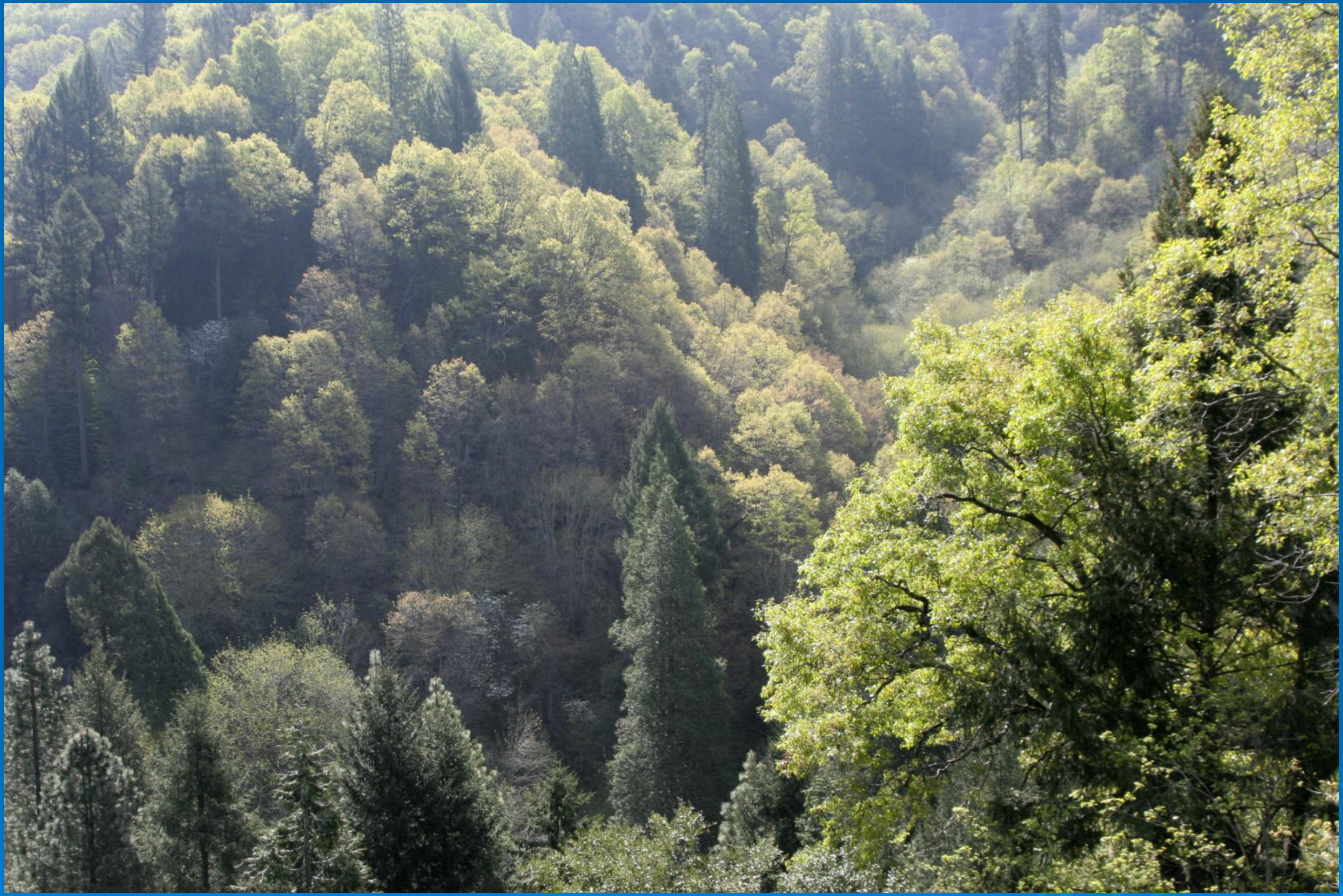
The Angora Fire, 2007 Photo by Steve DeVries



Distribution of the vegetation classes simulated for the historical (1961–1990) and GFDL-A2 future period (2070–2099). From Lenihan et al. 2008. Climatic Change 87: S215-S230



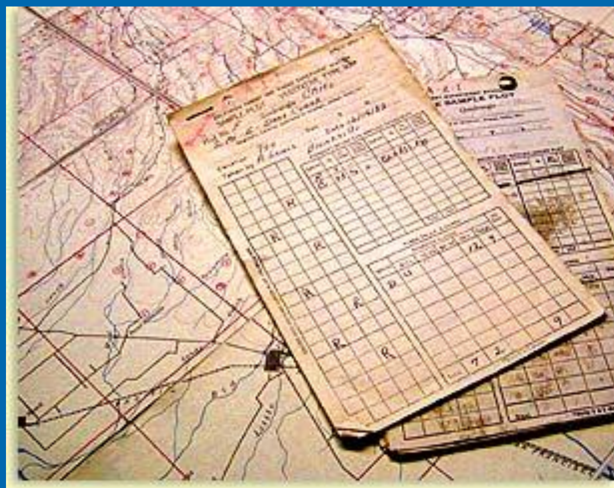
Changes in Calif. Vegetation Distribution 2070-2099, relative to 1961-1990.
From Lenihan et al. 2008. Climatic Change 87: S215-S230

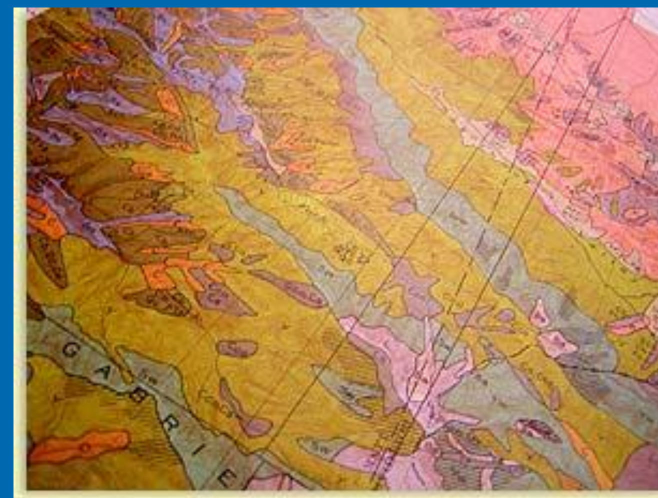


Is This the Future Tahoe Forest??

Pinus monophylla

Wieslander Vegetation Type Mapping





Albert Wieslander

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