Can We Plan for Global Warming?

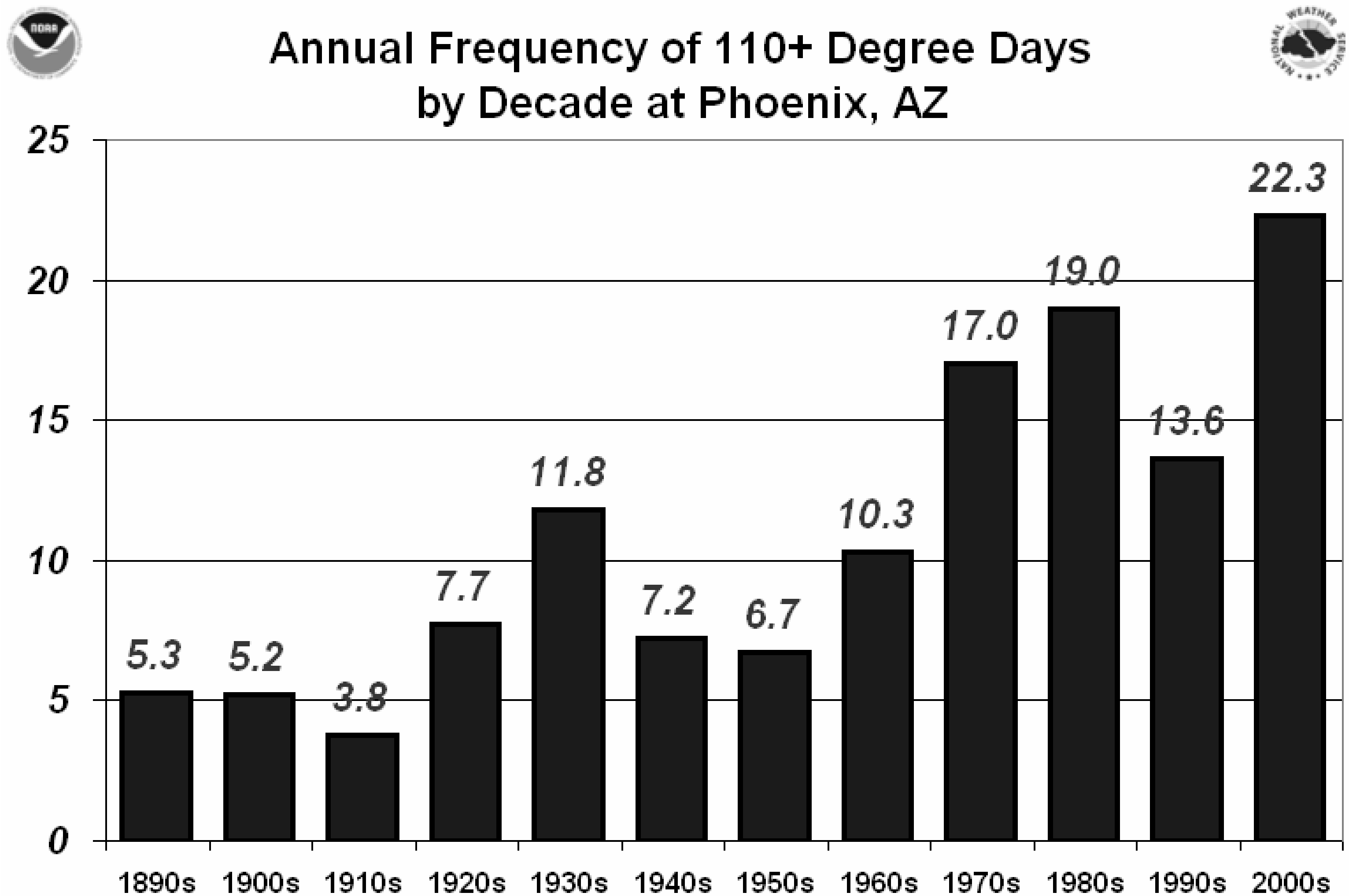
William R. Travis
Dept. of Geography UC-B
Boulder, CO

Adaptation Models

- <u>The Invisible Hand:</u> (Efficiency/equilibrium models): autonomous and incremental adjustments that balance costs and benefits.
- <u>The Wake Up Call:</u> (Hazards Model): GW will be experienced as “events” not trend, and all we know about hazards response will apply.
- <u>The Planning Model</u>: Apply improving information to identifying and assessing adaptations, up-date plans and regulations as conditions change.
- <u>Meta-models</u>: “development as adaptation”, fix inefficiencies and reduce dis-incentives and barriers to adapt as needed.

Modes of Climate Change

- Cumulative, uni-directional change that eventually exceeds planning and design thresholds.
- Changes in the frequency of discreet climate (heat waves), and climate-related, events (wildfire).
- Abrupt, severe climate change

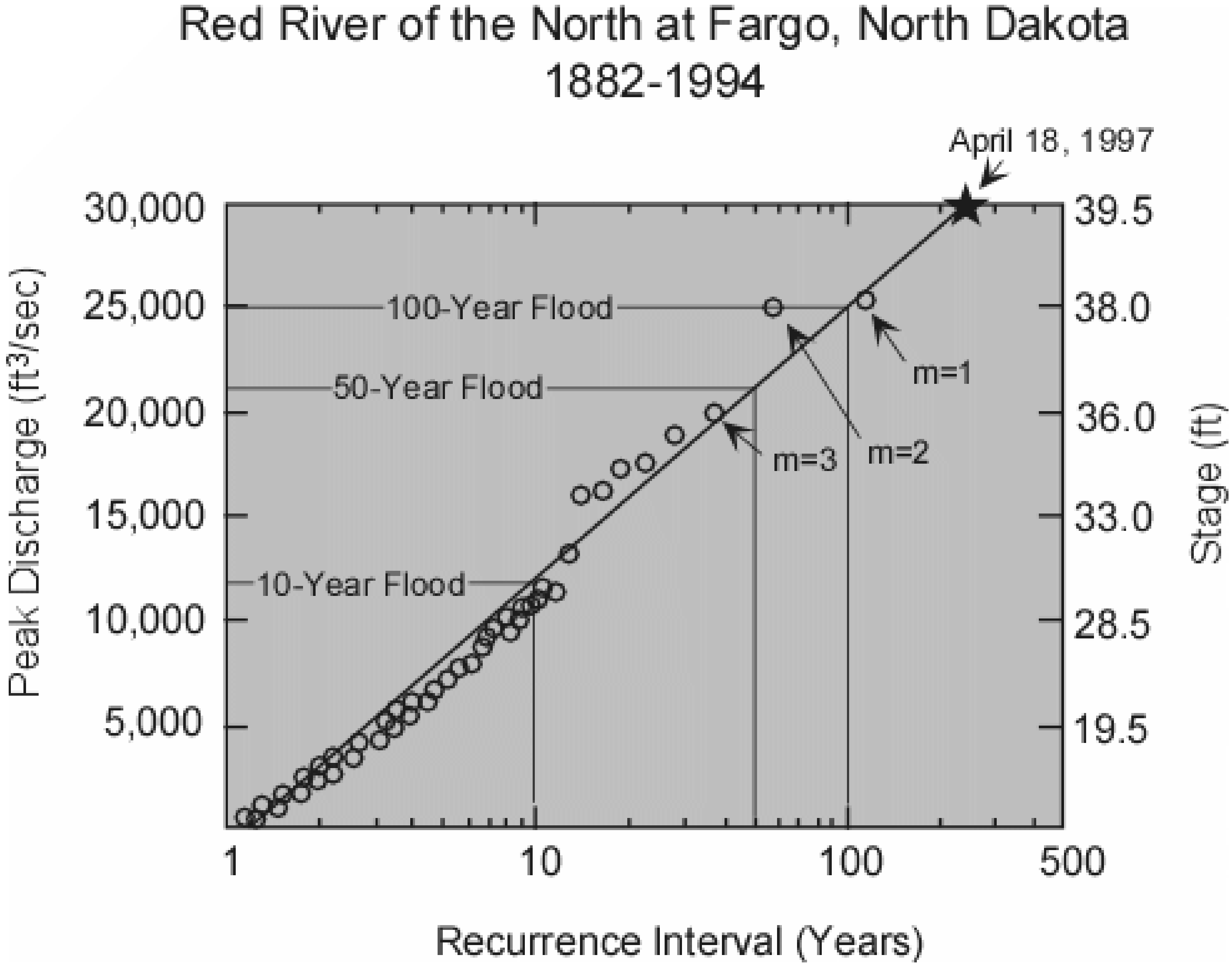

Annual Frequency of 110+ Degree Days
by Decade at Phoenix, AZ
25
20
15
10
5
0
5.3
5.2
3.8
7.7
11.8
7.2
6.7
10.3
17.0
19.0
13.6
22.3
1890s
1900s
1910s
1920s
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s

Planning Conundrum

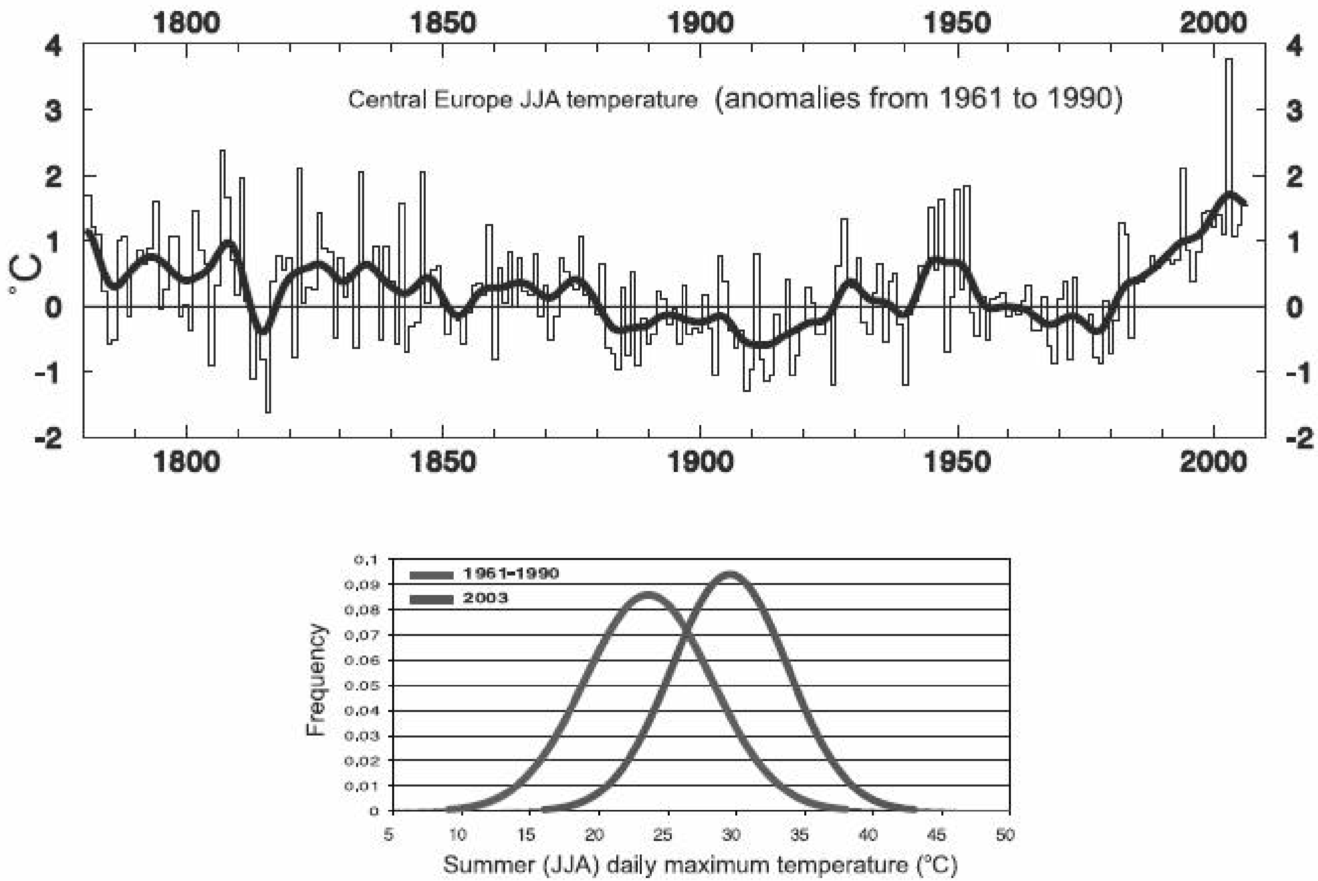
- How will you know the climate is changing / has changed?
  - Won’t be easy in very nosy elements like precipitation, or events like heat waves (dueling scientific articles about the 2003 European Heat-Wave).
- When will clients be convinced?
- Might some clients challenge regulations based on a changed climate?

Exceeding Expectations?

My local storm-water system has been exceeded several times in the 24 years I've lived on Gun Barrel Hill



Even big events can be incorporated into "normal" climate (see also 2004 hurricane season in Florida!)



Box 3.6, Figure 2. *Long time series of JJA temperature anomalies in Central Europe relative to the 1961 to 1990 mean (top). The smooth curve shows decadal variations (see Appendix 3.A). In the summer of 2003, the value of 3.8°C far exceeded the next largest anomaly of 2.4°C in 1807, and the highly smoothed Gaussian distribution (bottom) of maximum temperatures (red) compared with normal (blue) at Basel, Switzerland (Beniston and Diaz, 2004) shows how the whole distribution shifted.*

GOING TO THE EXTREMES

AN INTERCOMPARISON OF MODEL-SIMULATED HISTORICAL AND FUTURE CHANGES IN EXTREME EVENTS

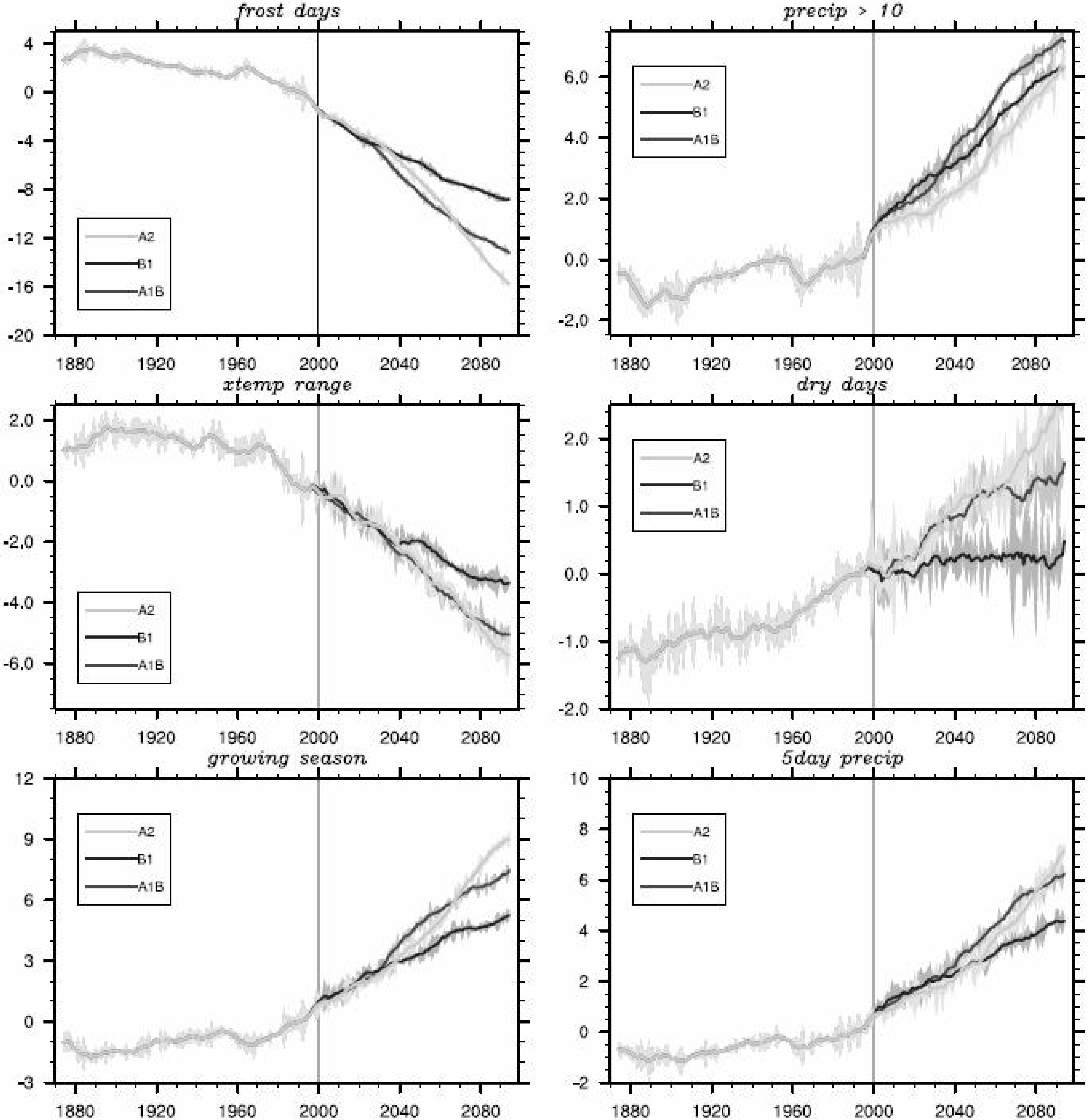
CLAUDIA TEBALDI[1], KATHARINE HAYHOE[2,3], JULIE M. ARBLASTER[4,5] and GERALD A. MEEHL[4]

[1]*Institute for the Study of Society and Environment, National Center for Atmospheric Research (NCAR), PO BOX 3000, Boulder, CO 80301*

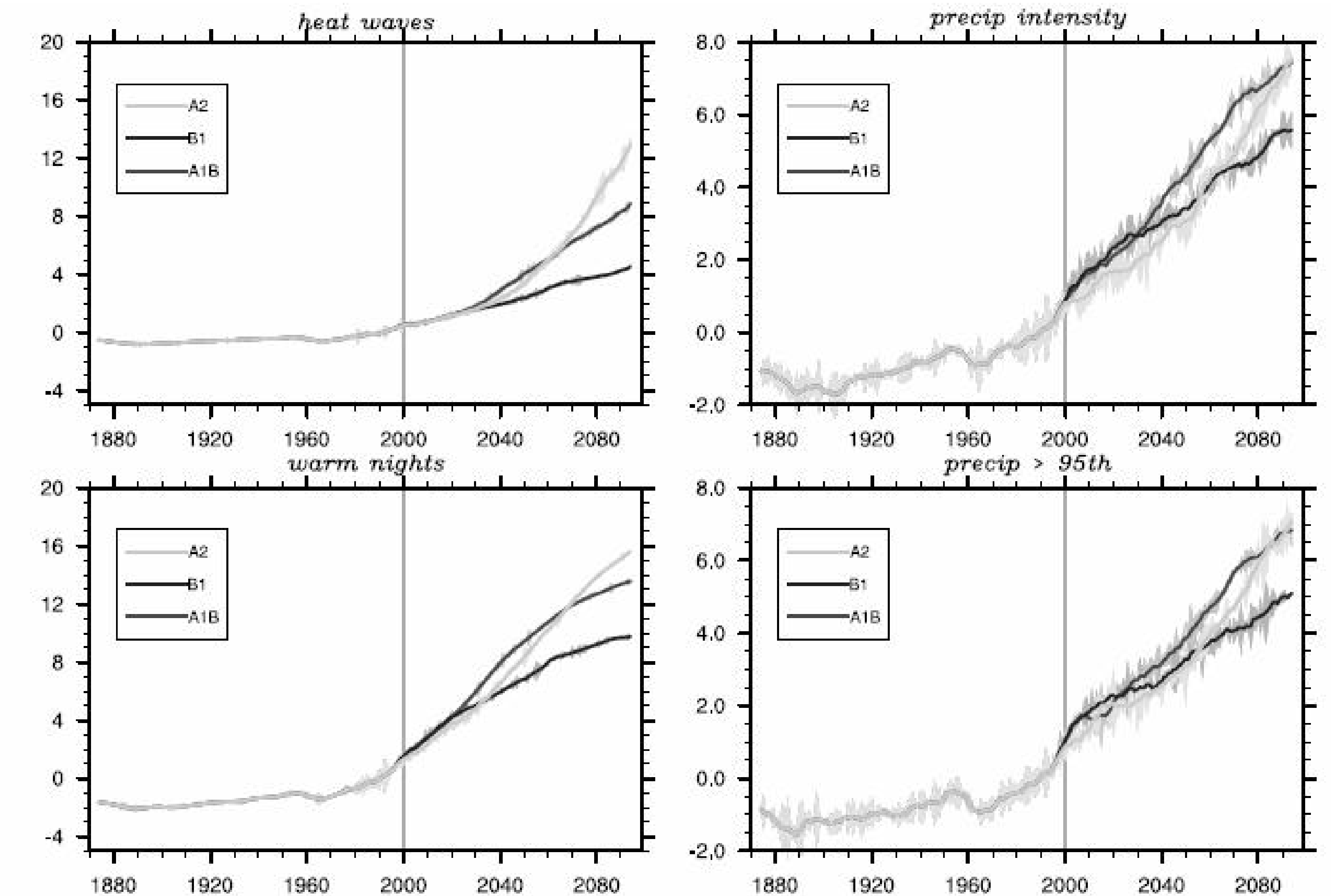
TABLE II

Summary of comparisons between observed and simulated trends (1960–2000) at the global average scale, discussed in Sections 3 and 4

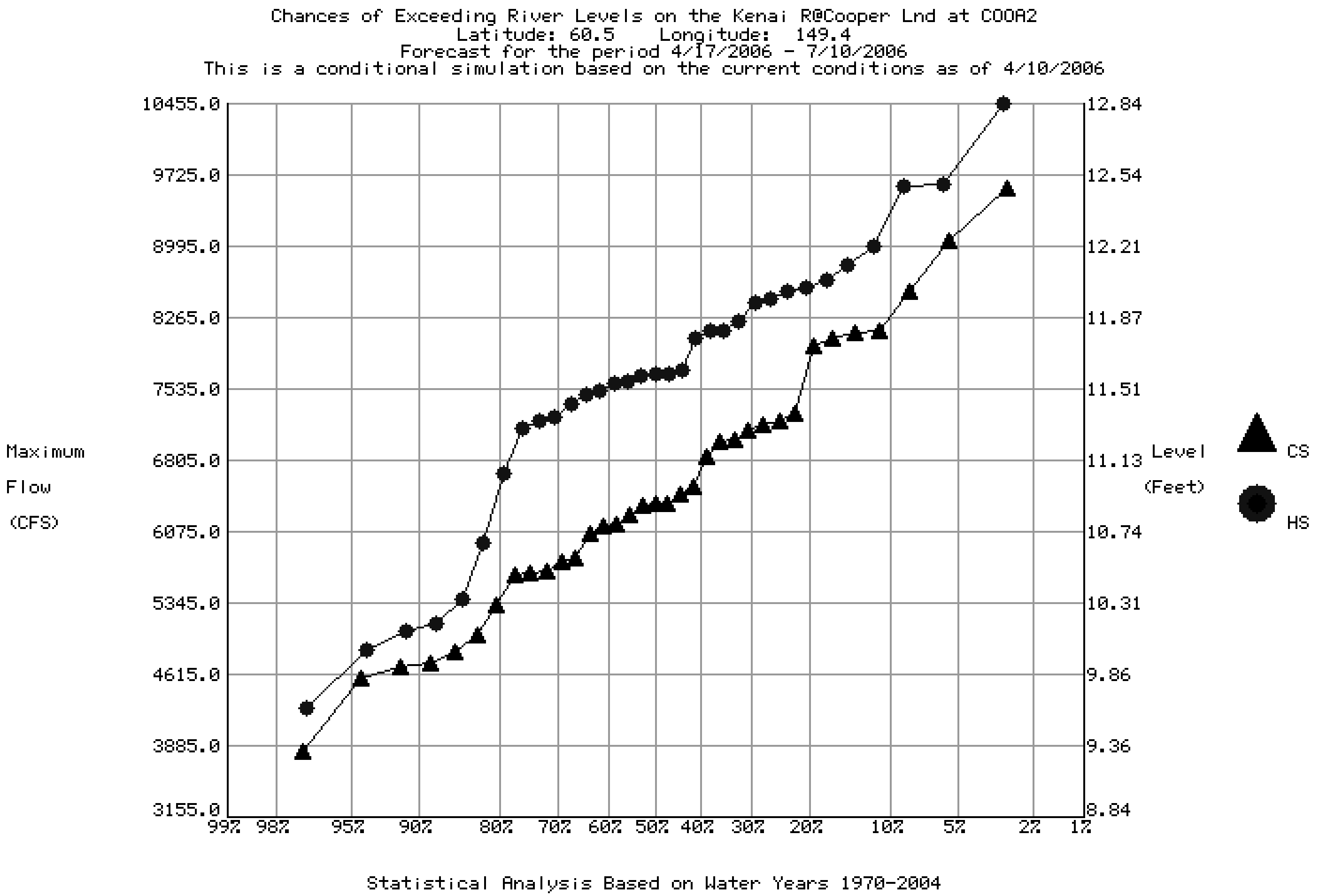
Index	Observed trends	Simulated trends
Frost days	Significant decreasing trend	Decreasing trend in all models Significant for a majority (Same for hemispheric averages)
Xtemp range	Significant decreasing trend	Decreasing trend in all models Significant for four models (SH sees disagreement in sign among models)
Growing season	Significant increasing trend	Increasing trend in all models Significant for a majority (Trends in SH flat for most models)
Heat waves	No significant trend	Increasing trend in all models Significant for four models (Same for hemispheric averages)
Warm nights	Significant increasing trend	Increasing trend in all models Significant for a majority (Same for hemispheric averages)
Precip >10	Significant increasing trend	Increasing trend for all models Significant for a minority High inter-annual and inter-model variability
Dry days	Significant decreasing trend	Increasing trend for all models Significant for a minority High inter-annual and inter-model variability



frost days
precip > 10
xtemp range
dry days
growing season
5day precip
A2
B1
A1B
1880
1920
1960
2000
2040
2080


heat waves
precip intensity
warm nights
precip > 95th
A2
B1
A1B
20
16
12
8
4
0
-4
8.0
6.0
4.0
2.0
0.0
-2.0
1880
1920
1960
2000
2040
2080

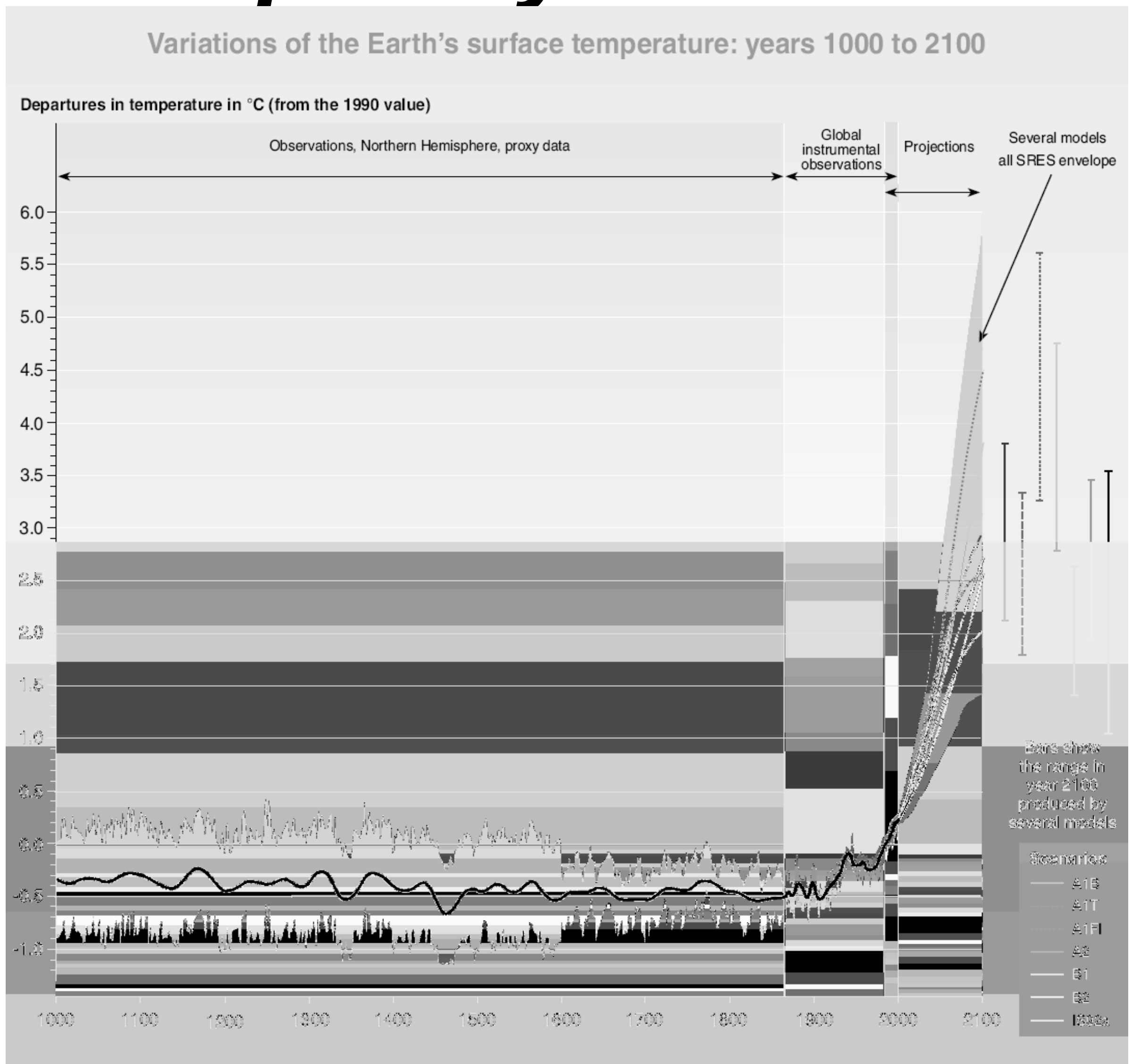
Climate Change can be very non-linear



Surprises, abrupt and dramatic change may rule a rapidly-warming world.

But, well-engineered systems may meet quite demanding standards, even 500 year return periods! They can absorb lots of climate change.

And Now, for Something Completely Different



Perceptions may force you to act even in absence of better predictions.

I wish I had his PowerPoint © technician!

Growing concern about abrupt, severe climate change

The Riebsame-Travis Scale of Climate Change Severity

Climate Change Severity Index	Description	Example Climate Phenomena	Social Responses	Additional population at Risk (billions)[1]
Zero	Means and extremes common to the recent (e.g., 30 year) climate	Current means and extremes	Those arrayed (more or less effectively) to absorb current variability	0
One	Small but statically-significant shifts away from the reference climate[2]	Scientific detection of climate change (signal surpassing noise) not necessarily sufficient to elicit social responses	Little to none as first small changes are absorbed by excess capacity and buffer built into socio-technical systems.	0
Two	Palpable changes in the frequency-intensity-duration of climate events that begin to surpass informal and formal socio-technical adaptive capacities	Noticeably more frequent, and more intense, climate events: like the 1988 U.S. drought and 2003 Europe heatwave	Adjustments in regulatory and technical systems such as shifted floodplain boundaries; storm surge evacuation zones; levee and dam enlargement, and changes in insurance coverage.	.1 to .5

	capacities			
Three	Extreme climate episodes rare in the past become typical; emergence of new types of extreme climate episodes or syndromes	Atlantic hurricane seasons like 2004/05, and the 2003 and 2005 European heat waves, become "typical" events. Frequent continental "mega-droughts" in North America and Asia and "exceptional droughts" in China; sea level rise .2-2 m / century.	Enlarged and novel intervention (e.g., weather modification) and protection schemes (e.g., new, encompassing sea walls; species relocation, and intra-continental water transfers)	3 each
Four	New climate epochs: Large-scale discontinuities and permanent change in regional climates	THC break down yielding significant cooling in N. Europe, enduring "intensified aridity" in SW North America; sea level rise of 2+ m/century	Geo-engineering attempts to cool the climate and prevent discontinuities, reverse trends like ice sheet melting, or even to restore past conditions	6 to maximum future global population ($GloPop_{max}$)
Five	Catastrophic climate change	Run-away greenhouse; Permian-like warm epoch	Social and ecological collapse	$GloPop_{max}$

Sciencexpress Report

Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America

Richard Seager,[1] Mingfang Ting,[1] Isaac Held,[2,3] Yochanan Kushnir,[1] Jian Lu,[4] Gabriel Vecchi,[2] Huei-Ping Huang,[1] Nili Harnik,[5] Ants Leetmaa,[2] Ngar-Cheung Lau,[2,3] Cuihua Li,[1] Jennifer Velez,[1] Naomi Naik[1]

[1]Lamont Doherty Earth Observatory of Columbia University, Palisades, NY, USA. [2]NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA. [3]Program in Atmospheric and Oceanic Sciences, Department of Geosciences, Princeton University, Princeton, NJ, USA. [4]National Center for Atmospheric Research, Boulder, CO, USA. [5]Tel Aviv University, Tel Aviv, Israel.

How anthropogenic climate change will impact hydroclimate in the arid regions of Southwestern North America has implications for the allocation of water resources and the course of regional development. Here we show that there is a broad consensus amongst climate models that this region will dry significantly in the 21st century and that the transition to a more arid climate should already be underway. If these models are correct, the levels of aridity of the recent multiyear drought, or the Dust Bowl and 1950s droughts, will, within the coming years to decades, become the new climatology of the American Southwest.

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reported that the average of all the States and parts of northern Mexico . Fig. 1 shows the modeled history and future of the annual mean precipitation minus evaporation (*P*–*E*) averaged over this region for the period common to all the models, 1900–2098. The median, 25th and 75th percentiles of the model *P*–*E* distribution and the median of *P* and *E* are shown. For cases in which there were multiple simulations with a single model these were averaged together before computing the distribution. *P*–*E* equals the moisture convergence by the atmospheric flow and, over land, the amount of water that goes into runoff.

In the multi-model ensemble mean there is a transition to a sustained drier climate that begins in the late 20th and early 21st centuries. In the ensemble mean both *P* and *E* decrease

Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity

A. L. Westerling,[1,2*] H. G. Hidalgo,[1] D. R. Cayan,[1,3] T. W. Swetnam[4]

Western United States forest wildfire activity is widely thought to have increased in recent decades, yet neither the extent of recent changes nor the degree to which climate may be driving regional changes in wildfire has been systematically documented. Much of the public and scientific discussion of changes in western United States wildfire has focused instead on the effects of 19th- and 20th-century land-use history. We compiled a comprehensive database of large wildfires in western United States forests since 1970 and compared it with hydroclimatic and land-surface data. Here, we show that large wildfire activity increased suddenly and markedly in the mid-1980s, with higher large-wildfire frequency, longer wildfire durations, and longer wildfire seasons. The greatest increases occurred in mid-elevation, Northern Rockies forests, where land-use histories have relatively little effect on fire risks and are strongly associated with increased spring and summer temperatures and an earlier spring snowmelt.

Wildfires have consumed increasing areas of western U.S. forests in recent years, and fire-fighting expenditures by federal land-management agencies now regularly exceed US$1 billion/year (*1*). Hundreds of homes are burned annually by wildfires, and damages to natural resources are sometimes extreme and irreversible. Media reports of recent, very large wildfires (>100,000 ha) burning in western forests have garnered widespread public attention, and a recurrent 34 years of western U.S. (hereafter, "western") wildfire history together with hydroclimatic data to determine where the largest increases in wildfire have occurred and to evaluate how recent climatic trends may have been important causal factors.

Competing explanations: Climate versus management. Land-use explanations for increased western wildfire note that extensive livestock grazing and increasingly effective fire suppression began in the late 19th and early

In contrast, climatic explanations posit that increasing variability in moisture conditions (wet/dry oscillations promoting biomass growth, then burning), and/or a trend of increasing drought frequency, and/or warming temperatures have led to increased wildfire activity (*13*, *14*). Documentary records and proxy reconstructions (primarily from tree rings) of fire history and climate provide evidence that western forest wildfire risks are strongly positively associated with drought concurrent with the summer fire season and (particularly in ponderosa pine–dominant forests) positively associated to a lesser extent with moist conditions in antecedent years (*13*–*18*). Variability in western climate related to the Pacific Decadal Oscillation and intense El Niño/La Niña events in recent decades along with severe droughts in 2000 and 2002 may have promoted greater forest wildfire risks in areas such as the Southwest, where precipitation anomalies are significantly influenced by patterns in Pacific sea surface temperature (*19*–*22*). Although corresponding decadal-scale variations and trends in climate and wildfire have been identified in paleo studies, there is a paucity of evidence for such associations in the 20th century.

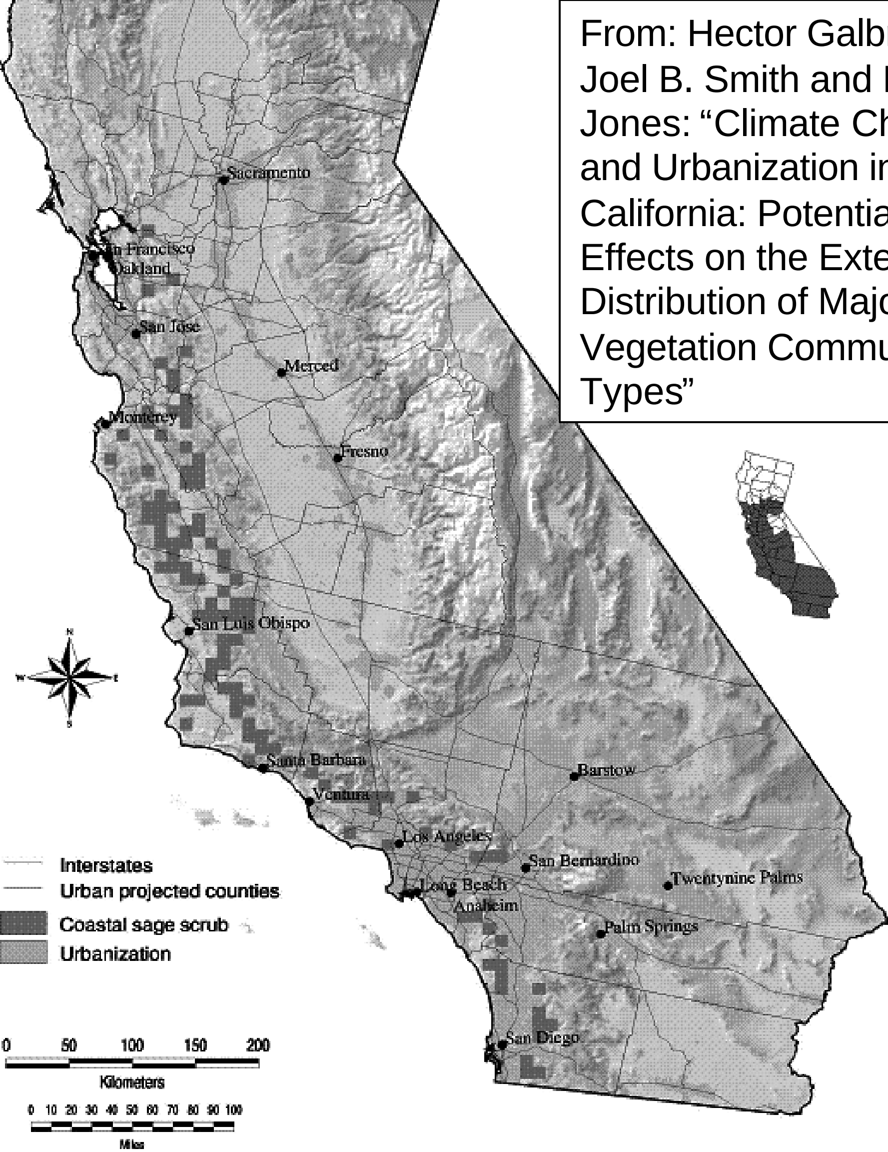
We describe land-use history versus climate as competing explanations, but they may be complementary in some ways. In some forest types, past land uses have probably increased the

What a planner to do?

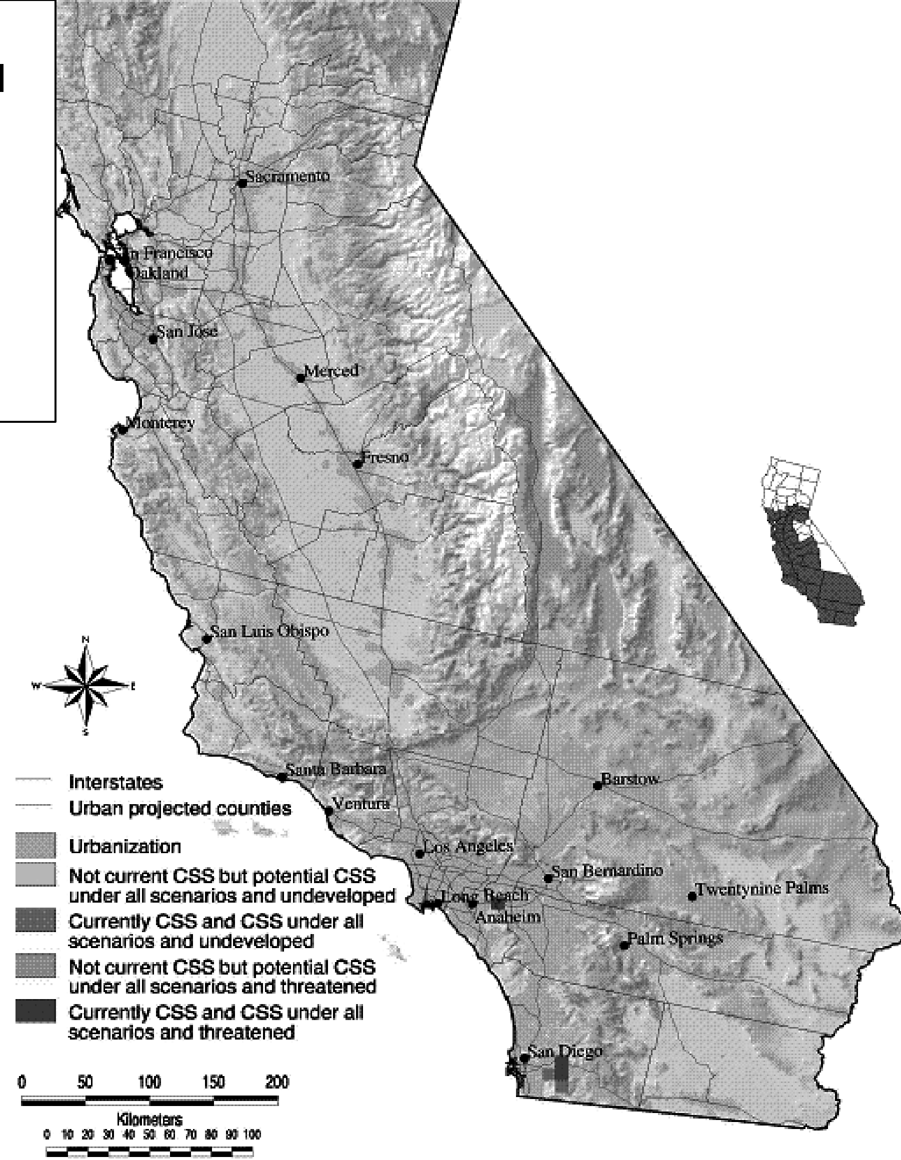
- Plan to plan
- Assess current climate sensitivities
- Conduct “What If” and
  Projection Studies
- Think about possible surprises
- Wait and See
- Worry

- Obtain and secure long-term local records climate and hydrology records, being especially careful to archive data that the state and feds may neglect.
- Identify sources of scientific advice on climate change, hydrology, ecology, etc.
- Examine current plans and ordinances for climate-sensitivities in three categories:
  - Plans with climate sensitivities but for which a <u>wait and see</u> approach makes sense;
  - Plans that are undermined by the mere existence of growing climate uncertainty, and need to be <u>reformed to deal with uncertainty</u>;
  - Plans that can be altered in light of <u>what we know now</u>.
- Explore plans for sensitivities to surprises and worst-case scenarios.

From: Hector Galbraith, Joel B. Smith and Russell Jones: “Climate Change and Urbanization in California: Potential Effects on the Extent and Distribution of Major Vegetation Community Types”



Their Figure 12b. Potential distribution of CSS by 2100 under the T3P18 climate change scenario and 92 million population



Their Figure 13. Potential distribution of CSS by 2100 under all climate change scenarios and 92 million population scenario

The End

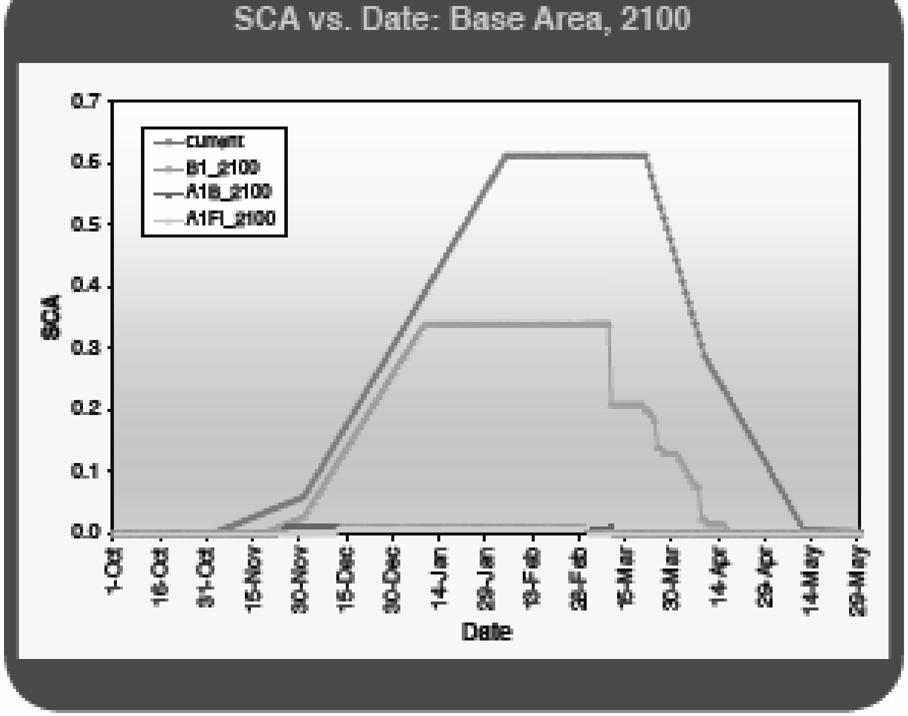


FIGURE 3.10: Modeled snow covered area (SCA) time series for zone 2 (8300-9300 ft.) of Aspen Moun-

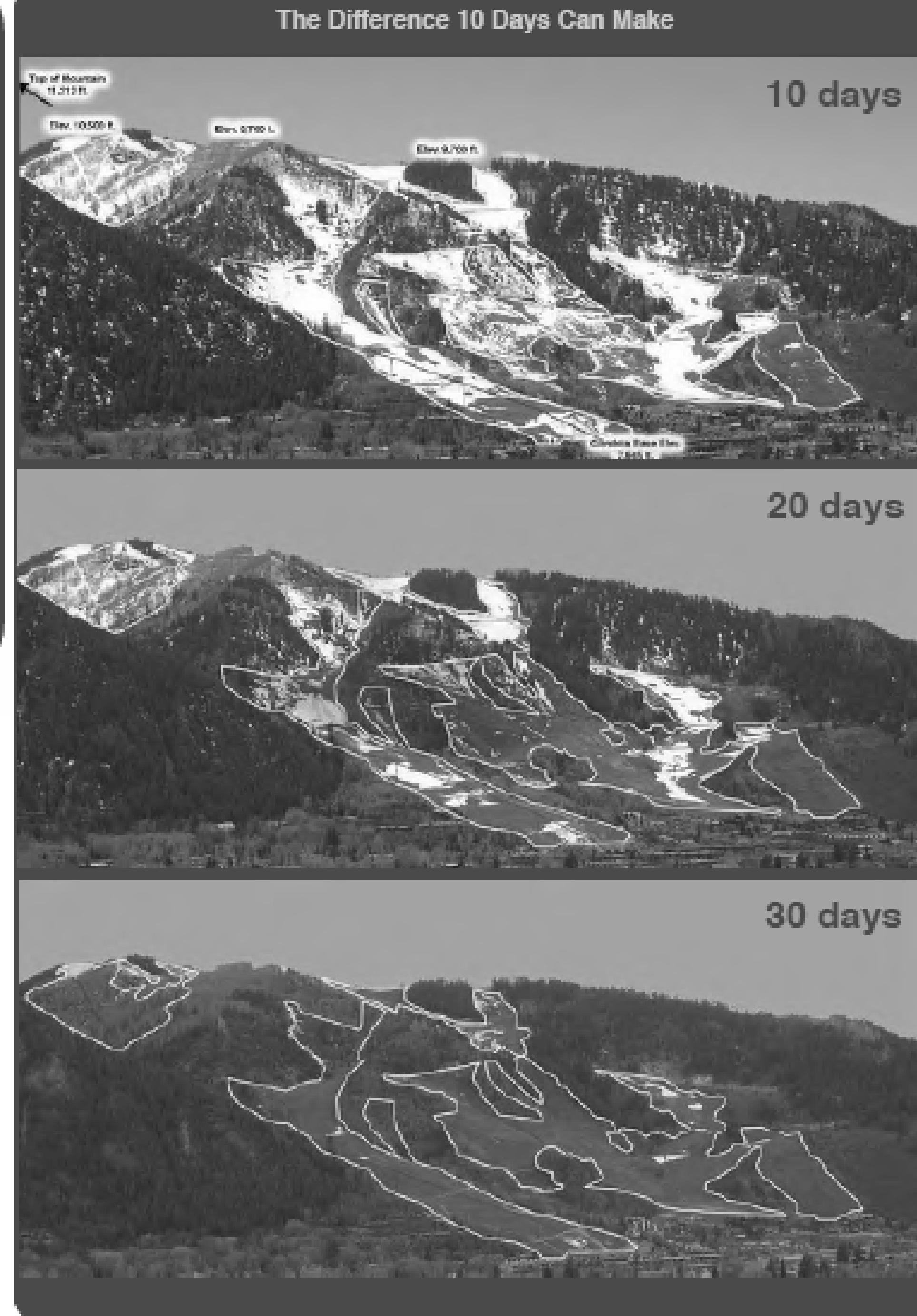
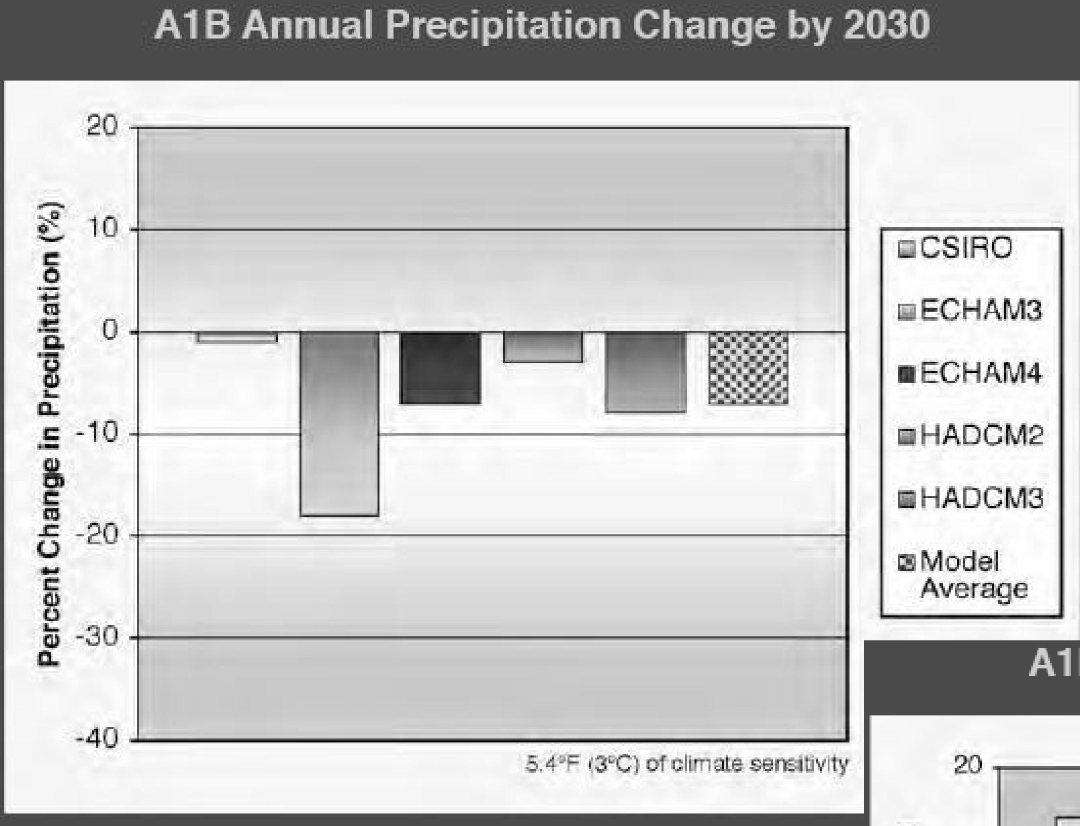
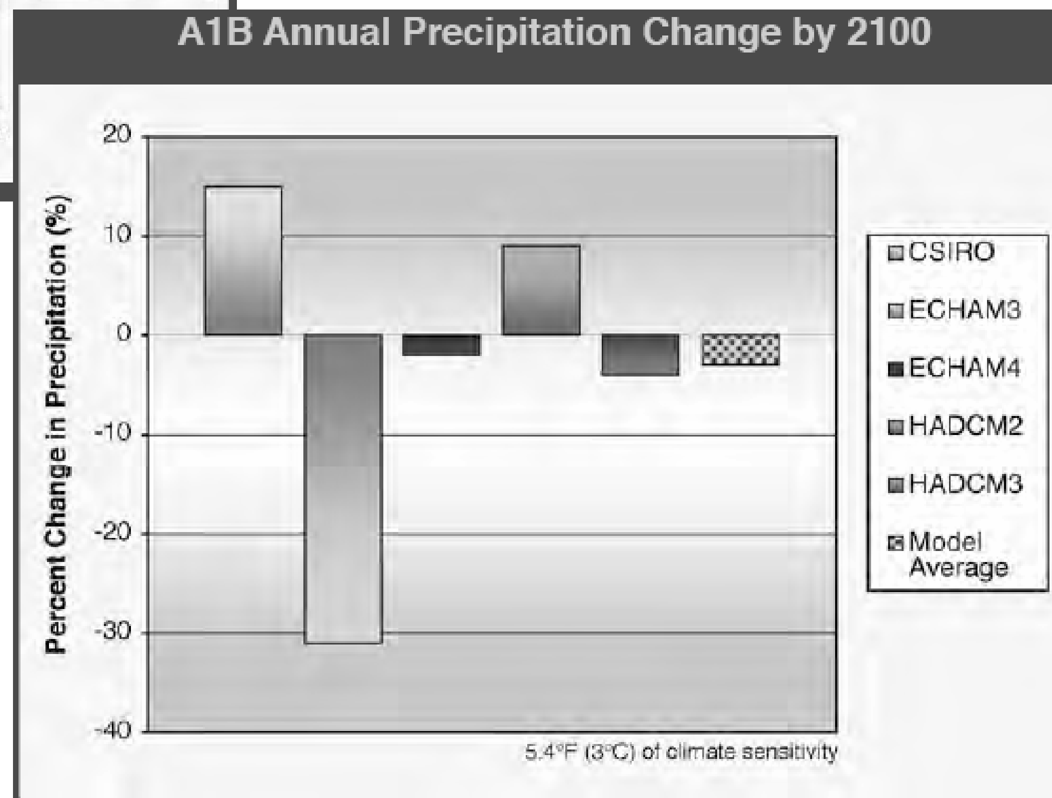


FIGURE ES.6: The difference 10 days can make. Three views of Aspen Mountain taken from Smuggler Mountain 10, 20, and 30 days after closing-day April 16, 2006. On closing day, the Aspen Skiing Company reported 100 percent of beginner and 97 percent of advanced and expert terrain

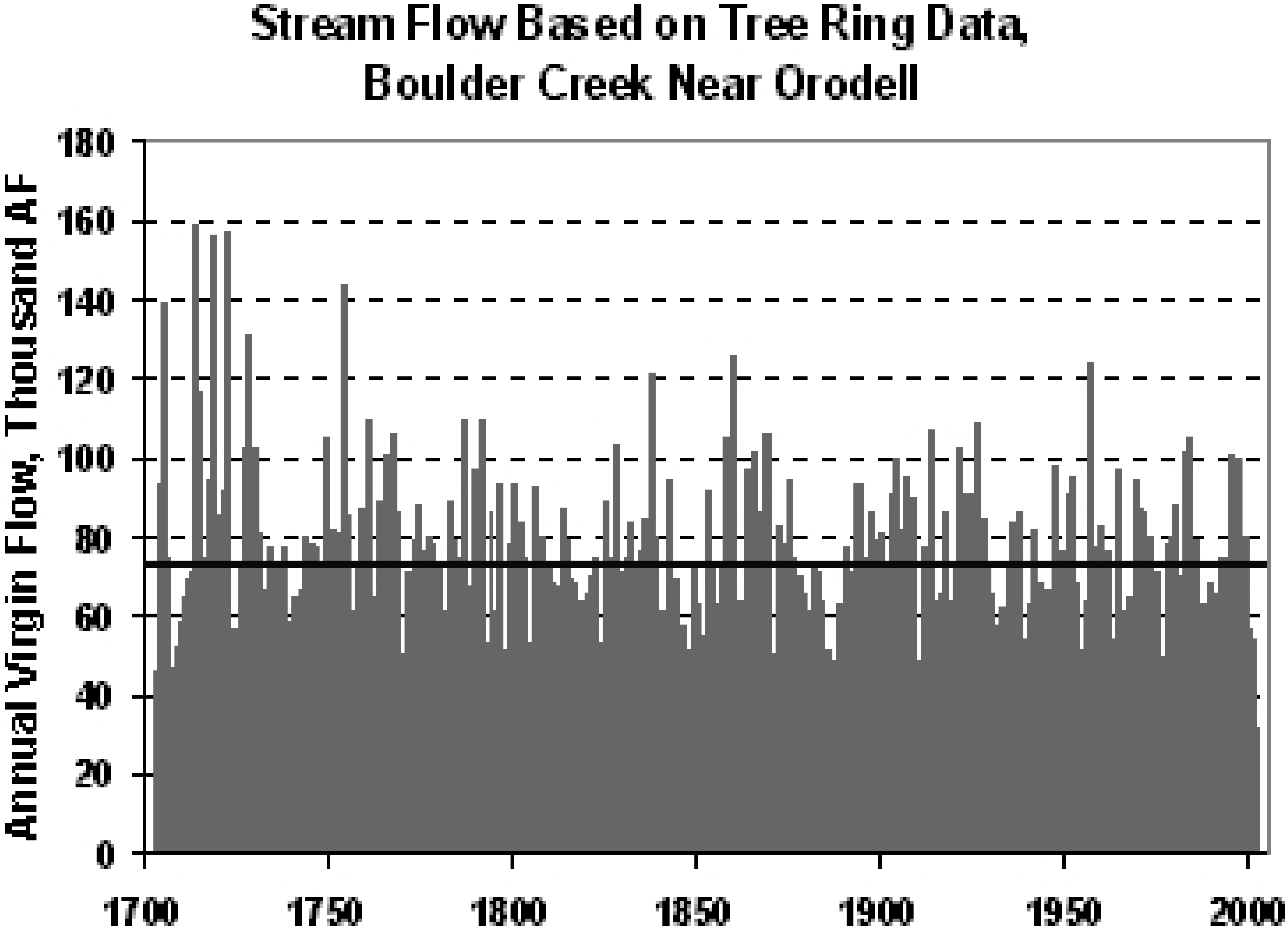
The Aspen story: Looks bad for skiing, but not all the scenarios were “bad.”

When we discussed “adaptation” the ski managers



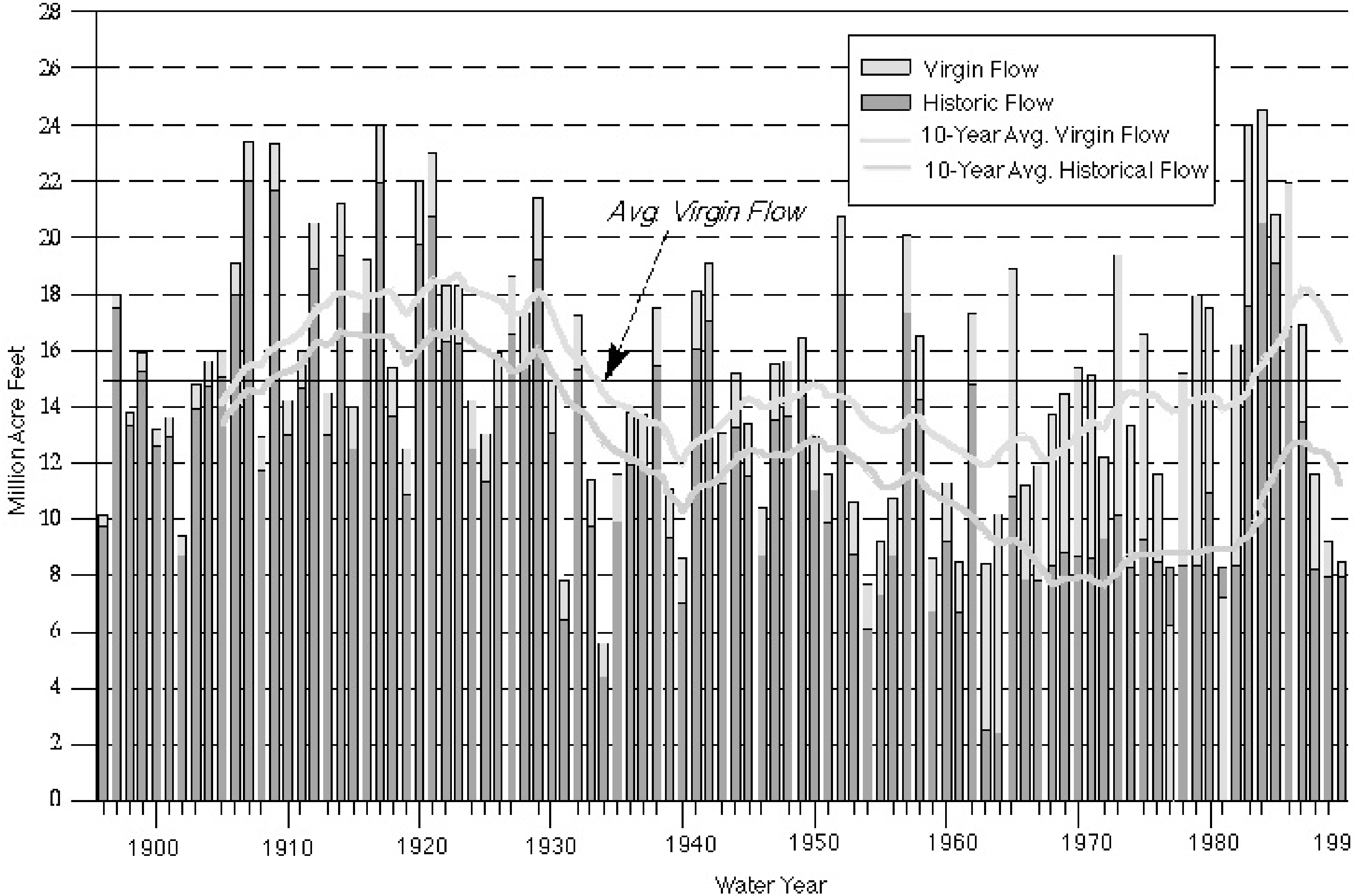


From: Aspen Global Change Institute, *Aspen and Climate Change: An Assessment of Impacts and Potential Responses* (Aspen, 2006).

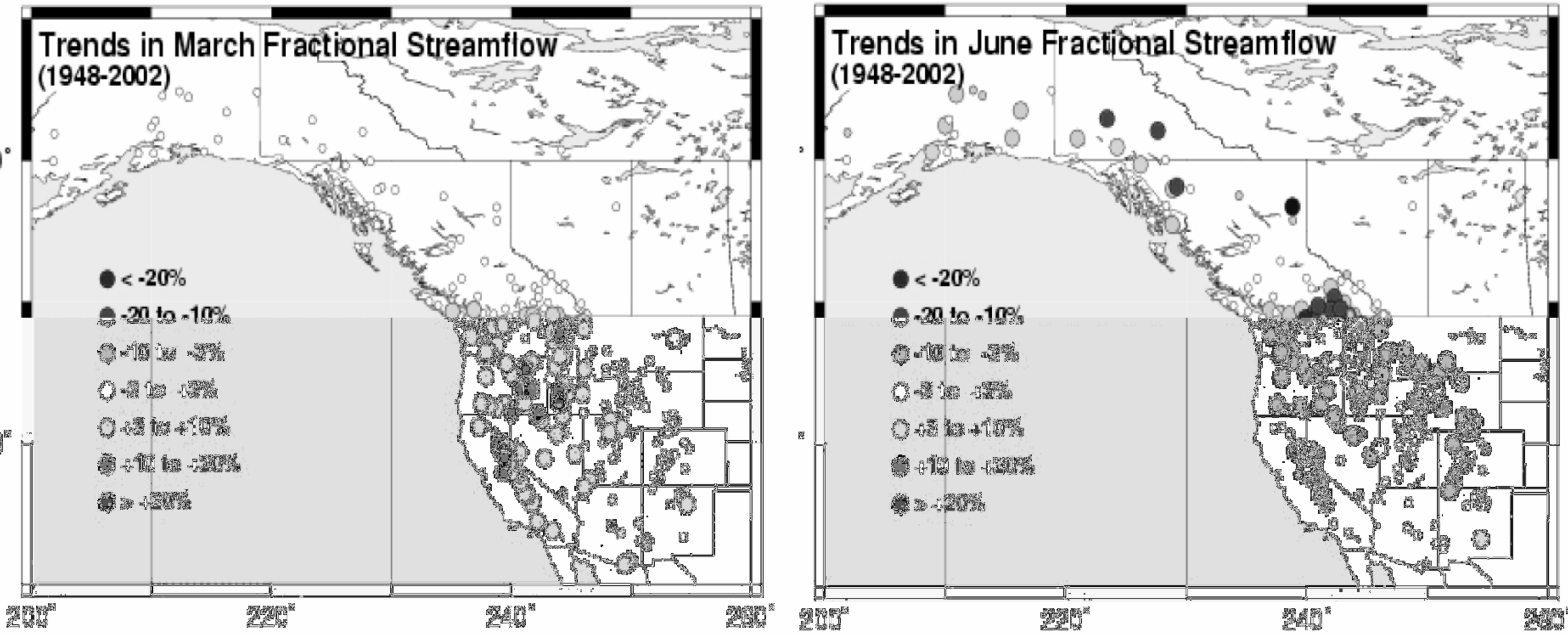


Variability is a problem in most water systems, including the Boulder Creek watershed that supplies the city.

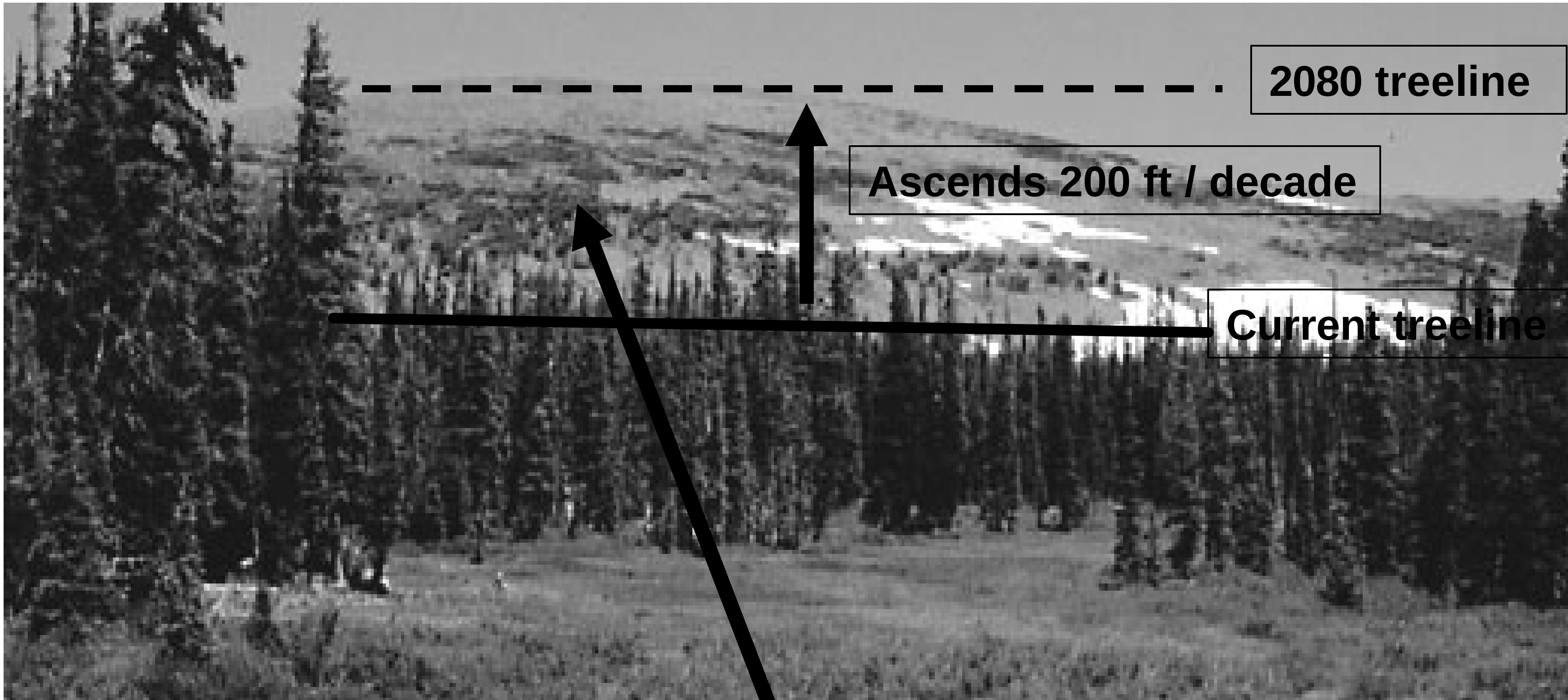
Colorado River Flow at Lee Ferry, Arizona



……*Spring is Coming Earlier in the West*



After Stewart, Cayan, and Dettinger (2005)



Even relatively slow change can seem “fast” (even abrupt) if you are fixed in place, like this tundra plant, and a boundary passes by you.

Where it matters most

- Planning via climate-sensitive performance criteria or thresholds (e.g., Tahoe Regional Planning Authority)
- Investments degraded by climate change (habitat and species protection)
- Public safety / hazards planning / protective works