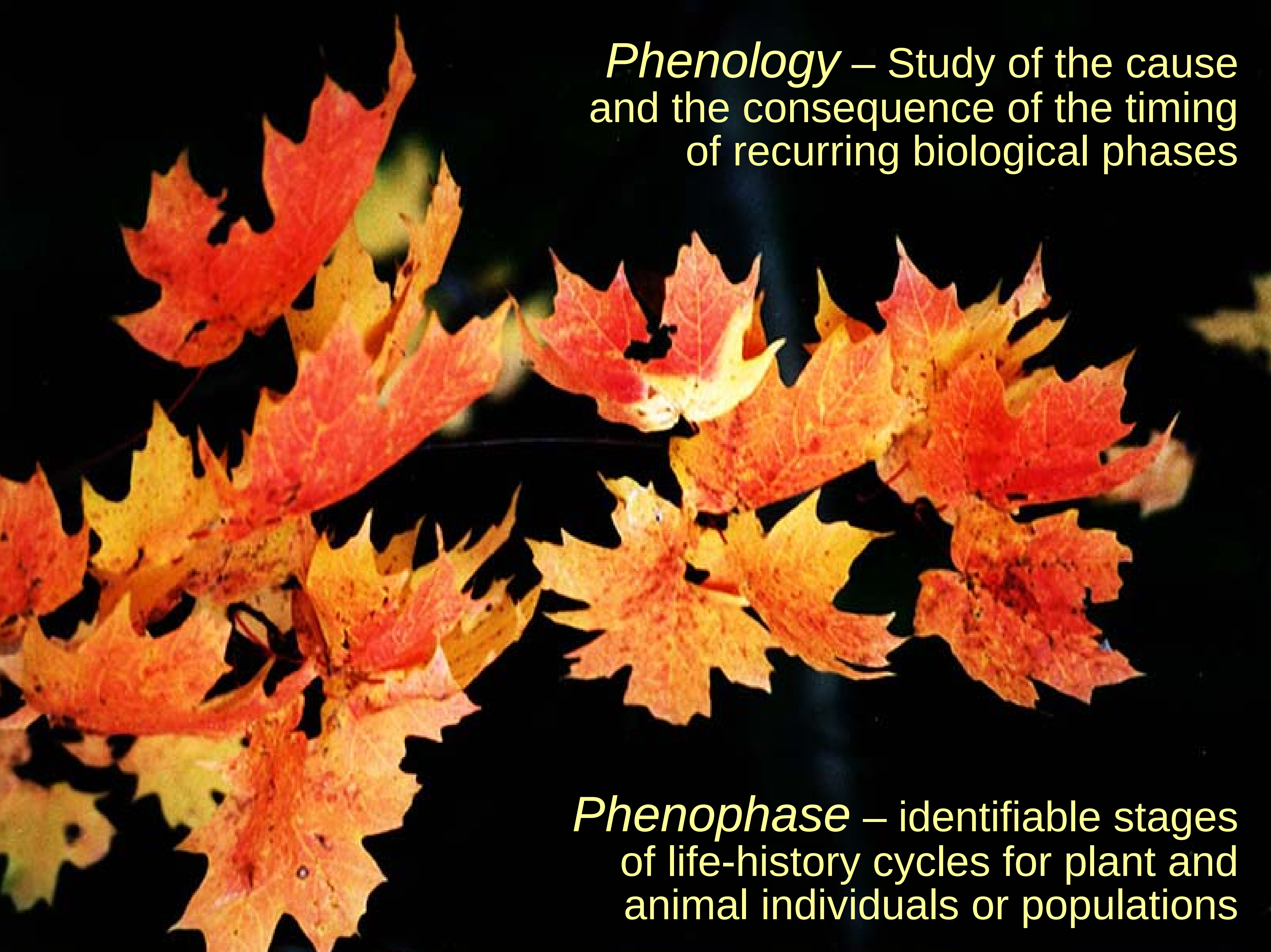
Phenology as an integrative science for assessment of global change impacts: The USA National Phenology Network

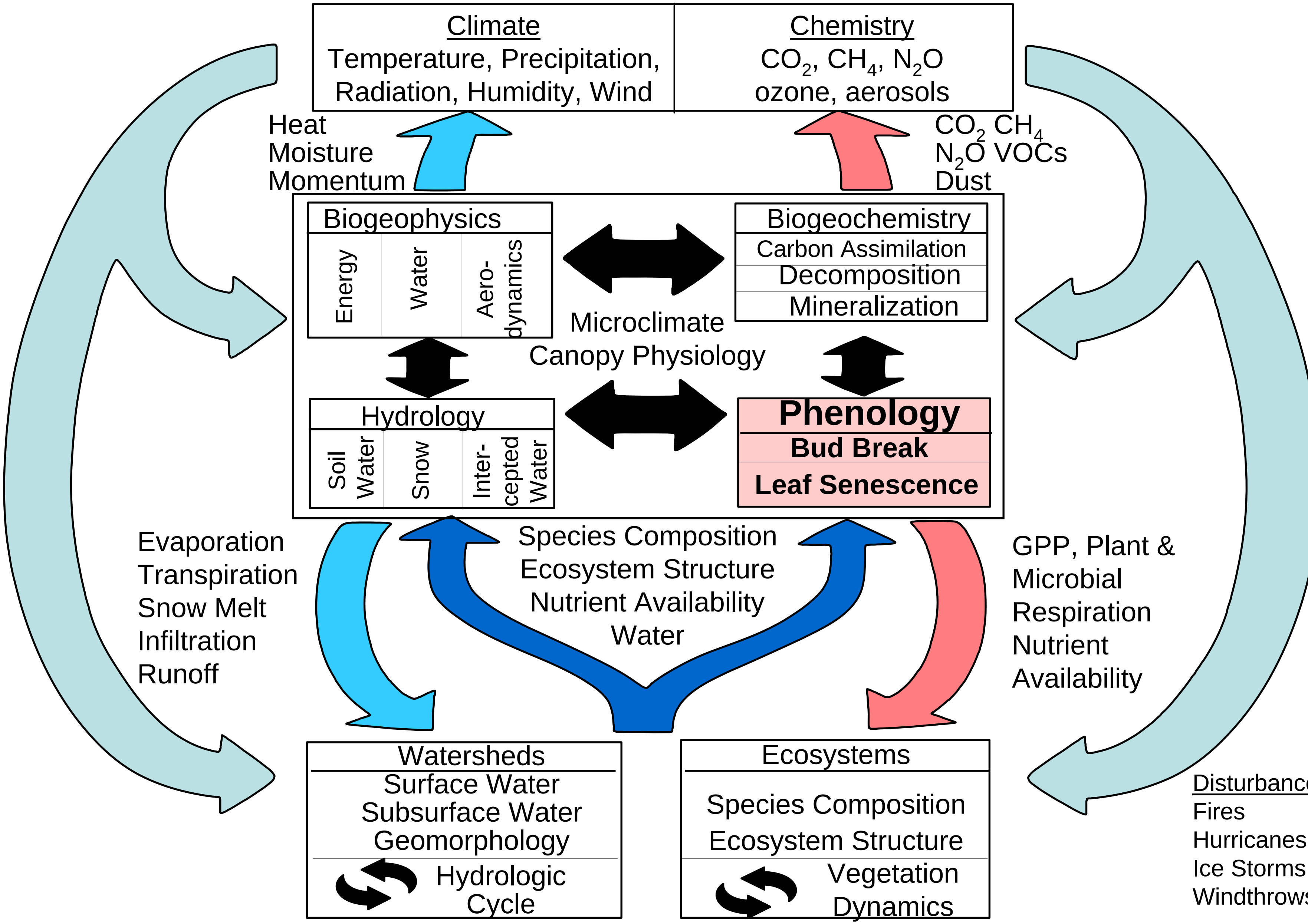
Mark Losleben

National Phenology Network
University of Arizona

www.usanpn.org


Phenology – Study of the cause and the consequence of the timing of recurring biological phases
Phenophase – identifiable stages of life-history cycles for plant and animal individuals or populations

Phenology and the biosphere



Betancourt 2006, modified from Bonan (2002)

Climate Change Phenology Thread

The Length of the Growing Season

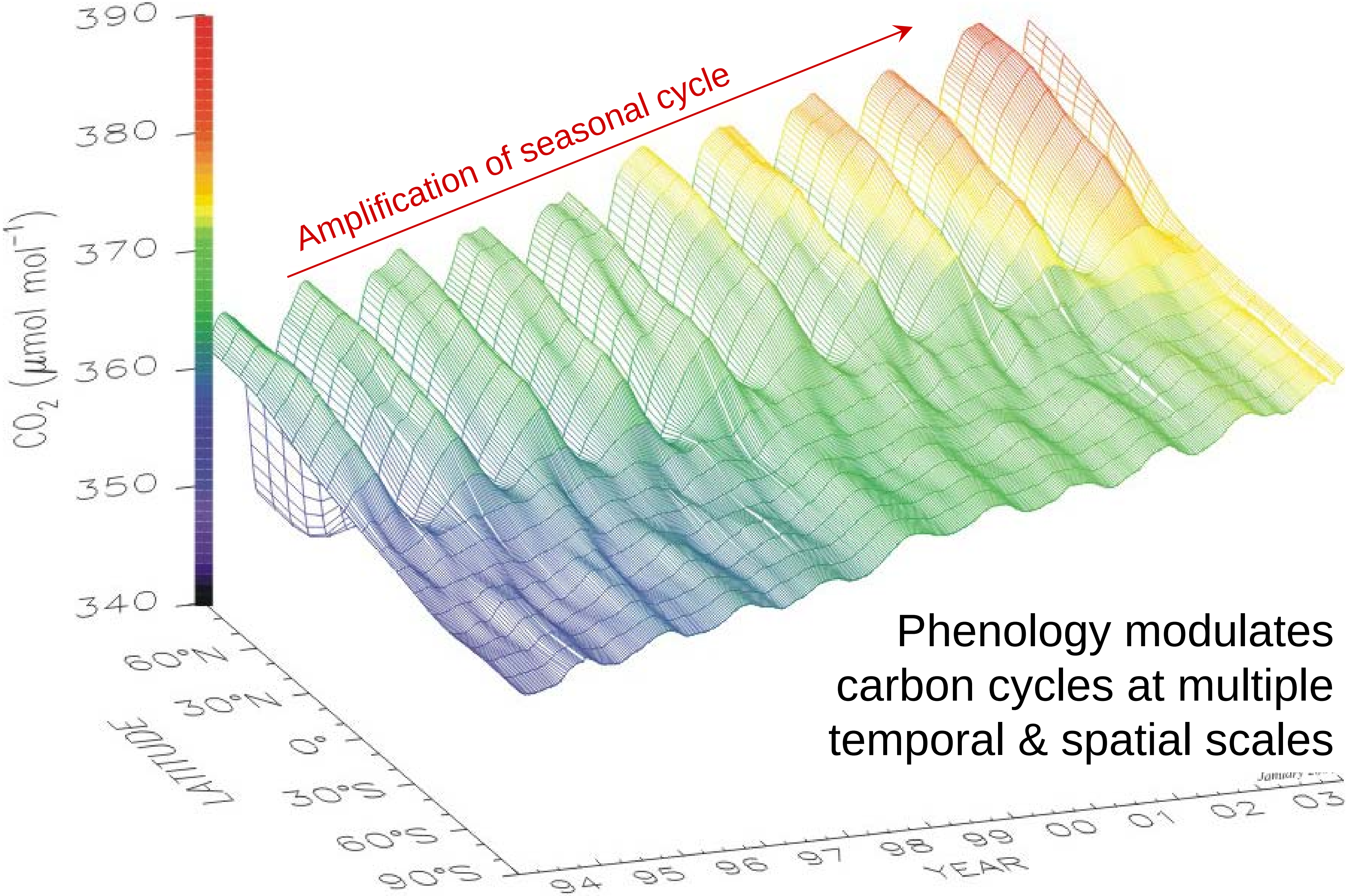
- Increase mostly related to earlier Spring Onset (2 weeks mid & high north lats. IPCC)

- Significant effects on annual Carbon and Water exchange
  - As long as Warmer Springs are not followed by Summer Drought

- Directly Related to Ecosystem Productivity

- The correspondence between soil temperature and mean annual air temperature has a strong correlation with Spring Leaf-out
  - The metric does not need tuning/calibration and works across a wide latitudinal range.

Global change influences & is influenced by phenology



Phenology modulates carbon cycles at multiple temporal & spatial scales

New modeling study in 02/02/08 Science: trends in warmer winters, less snowpack & earlier streamflow in West mostly due to greenhouse gases

Sciencexpress Report

Human-Induced Changes in the Hydrology of the Western United States

Tim P. Barnett,[1]* David W. Pierce,[1] Hugo G. Hidalgo,[1] Celine Bonfils,[2] Benjamin D. Santer,[2] Tapash Das,[1] Govindasamy Bala,[2] Andrew W. Wood,[3] Toru Nozawa,[4] Arthur A. Mirin,[2] Daniel R. Cayan,[1] Michael D. Dettinger[1]

[1]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093, USA. [2]Lawrence Livermore National Laboratory, Livermore, CA 94550, USA. [3]Land Surface Hydrology Research Group, Civil and Environmental Engineering, University of Washington, Seattle, WA 98195, USA. [4]National Institute for Environmental Studies, 16-2, Onogawa, Tsukuba, Ibaraki 305-8506, Japan.

*To whom correspondence should be addressed. E-mail: tbarnett-ul@ucsd.edu

Observations have shown the hydrological cycle of the western U.S. changed significantly over the last half of the twentieth century. Here we present a regional, multivariable climate-change detection and attribution study, using a high-resolution hydrologic model forced by global climate models, focusing on the changes that have already affected this primarily arid region with a large and growing population. The results show up to 60% of the climate related trends of river flow, winter air temperature and snow pack between 1950-1999 are human-induced. These results are robust to perturbation of study variates and methods. They portend, in conjunction with previous work, a coming crisis in water supply for the western United States.

Water is perhaps the most precious natural commodity in the western United States. Numerous studies indicate the hydrology of this region is changing in ways that will negatively impact the region (*1–3*). Between 1950 and 1999 simultaneous hydro climatic changes observed already differ significantly in length and strength from trends expected due to natural variability (detection), and differ in the specific ways expected of human-induced effects (attribution). Focusing on the hydrological cycle allows us to assess the origins of the most relevant climate-change impacts in this water-limited region.

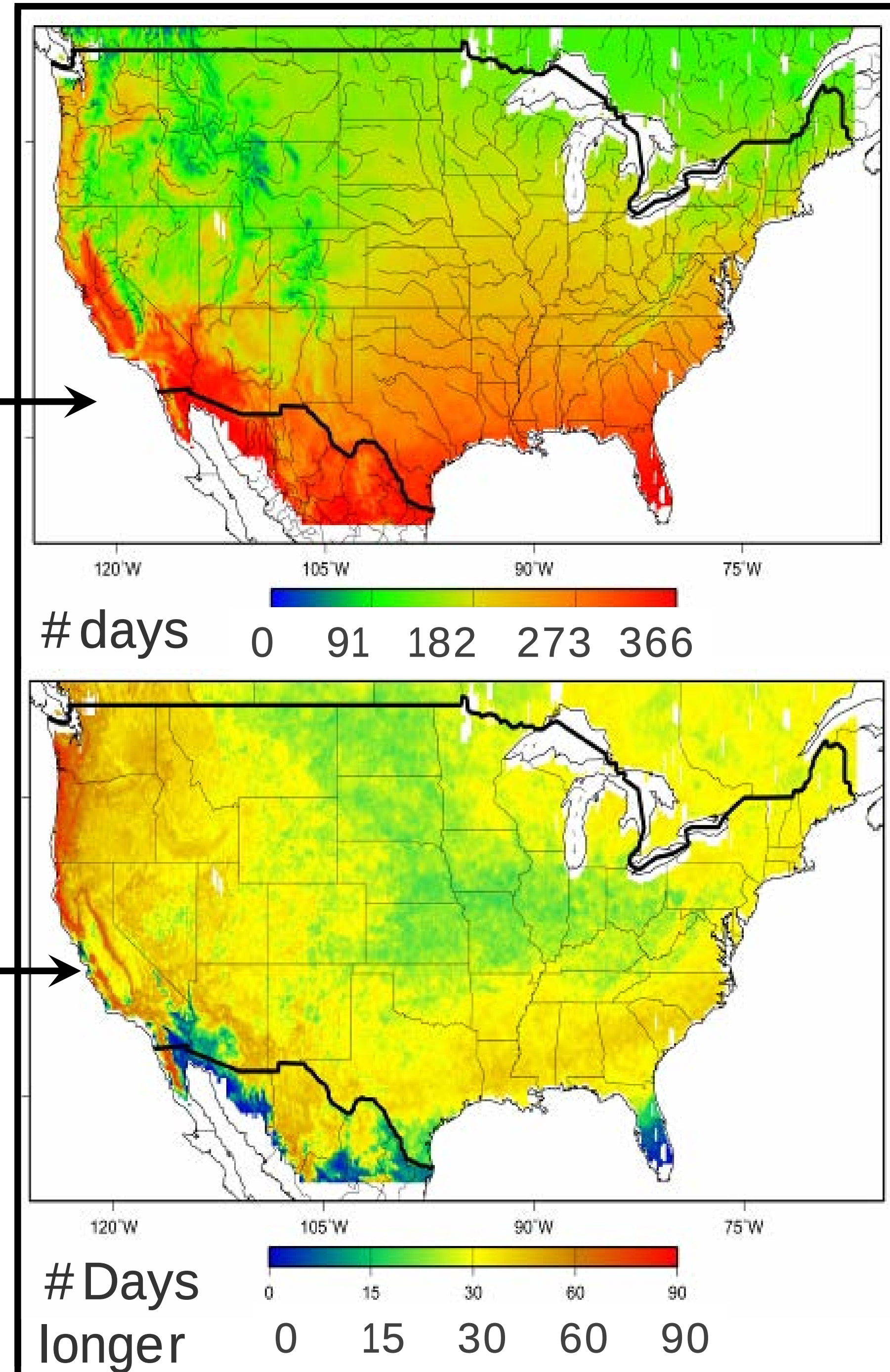
We investigate simultaneous changes from 1950-1999 (*19*) in snow pack (snow water equivalent or SWE), the timing of runoff of the major western rivers, and average January through March daily minimum temperature (JFM T_{min}) in the mountainous regions of the western U.S. (*20*). These three variates arguably are among the most important metrics of the western hydrological cycle. By using the multivariable approach we obtain greater signal to noise ratio than from univariate D&A alone (see below).

The SWE data are normalized by October-March precipitation (P) to reduce variability from heavy or light precipitation years. Observed SWE/P and temperature were

Growing season length should change more in West

Mean length growing season 1950-1999, defined as longest interval in a given year with no daily mean temp. in 3-day periods < 5ºC

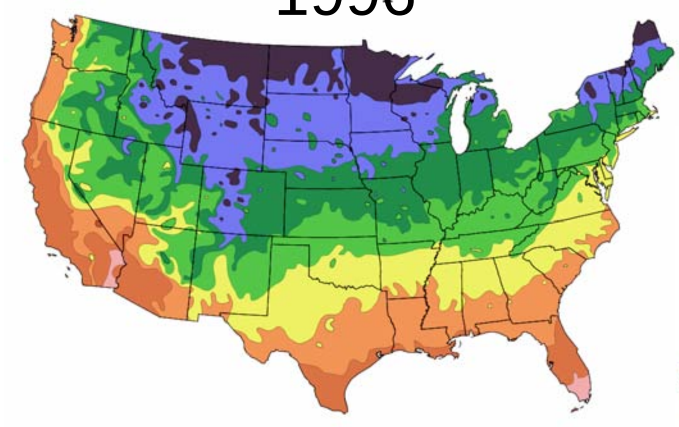
Different sensitivities with uniform 3ºC warming due to greater importance of advective over radiative freezing in the East & Midwest



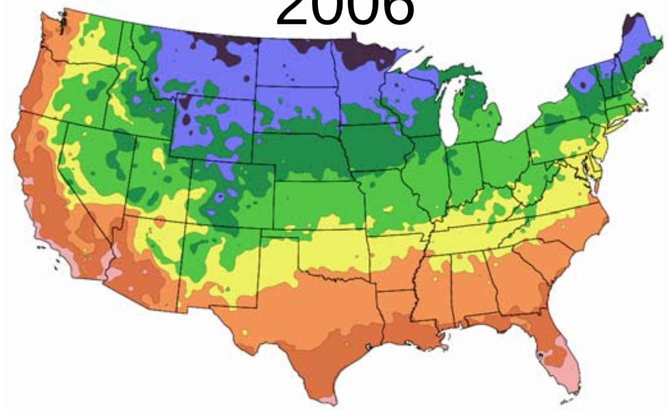
Courtesy of M. Dettinger

Winter Hardiness Maps

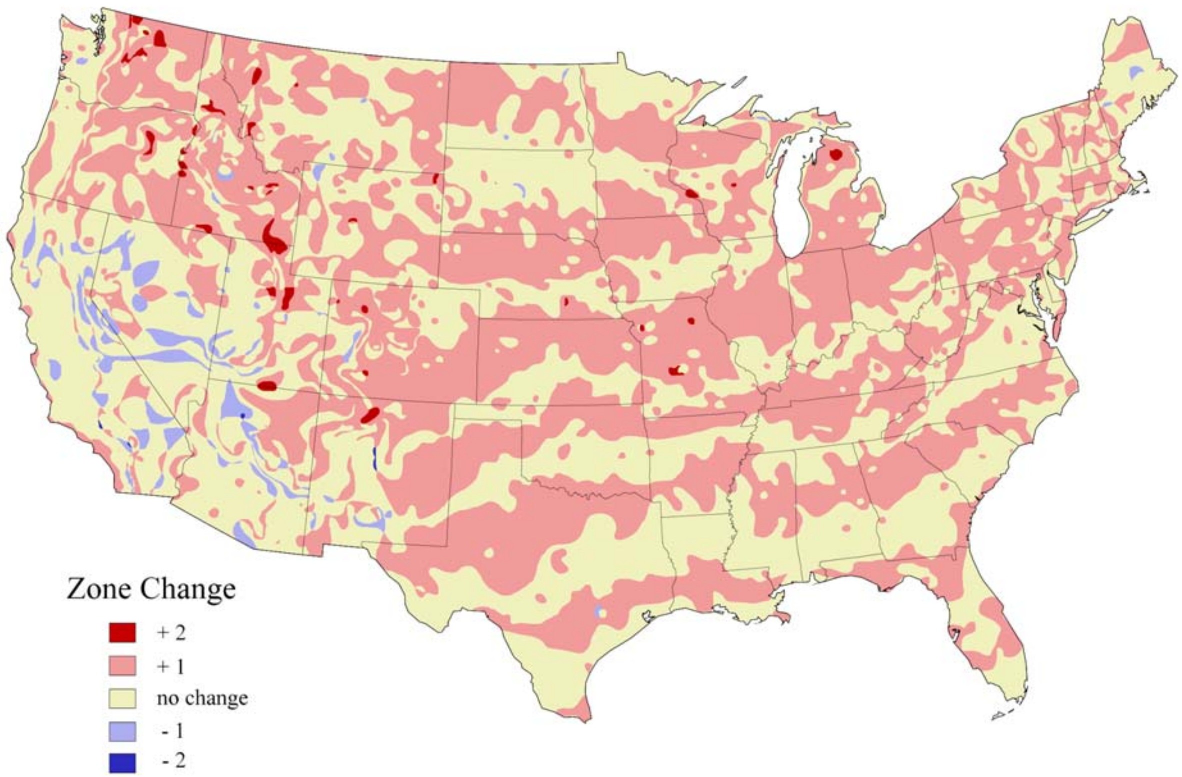
1996



2006



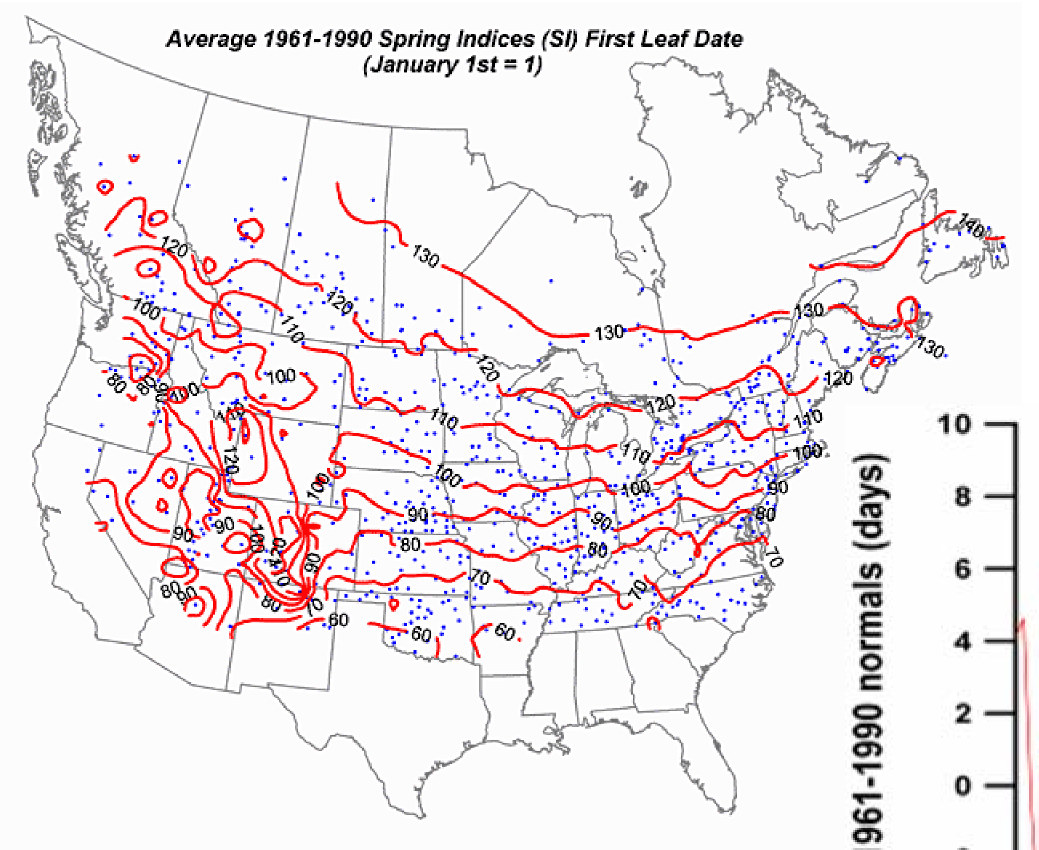
Zone #

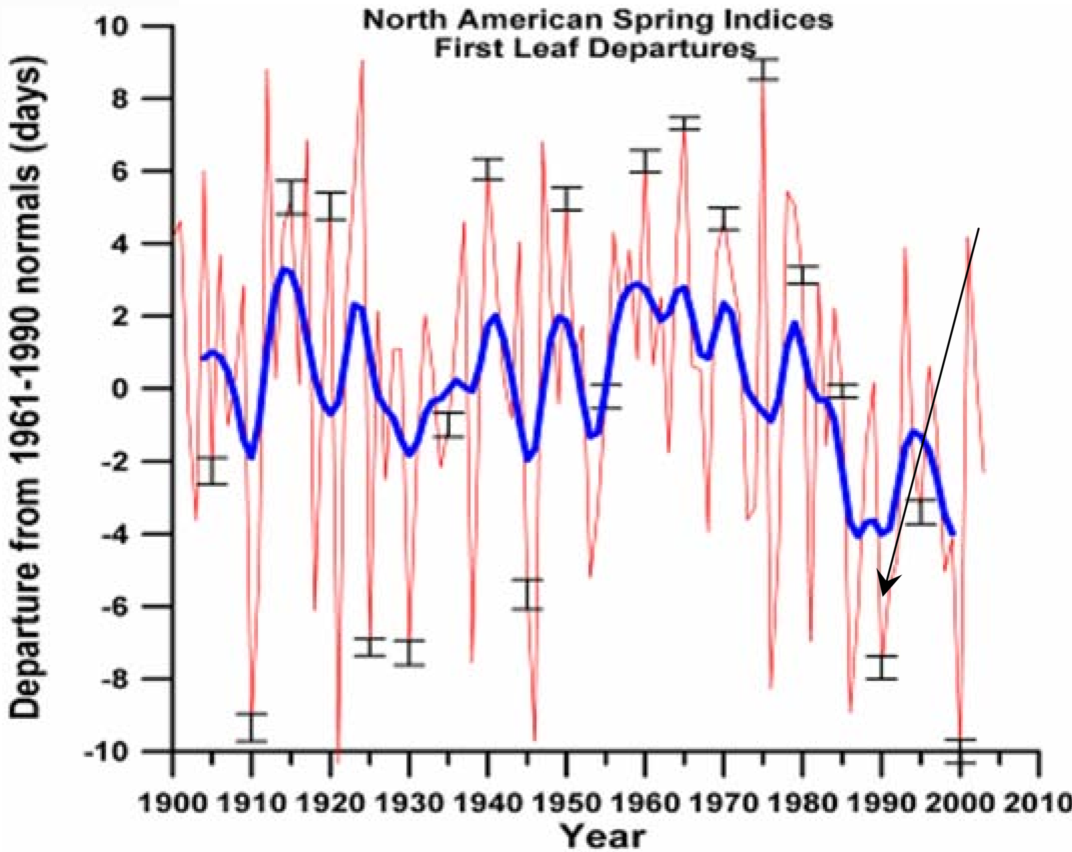


Difference from 1996 to 2006

National Arbor Day Foundation

Spring index based on first leaf date for lilacs





Syringa vulgaris
(common lilac)
Syringa chinensis
(cloned lilac)

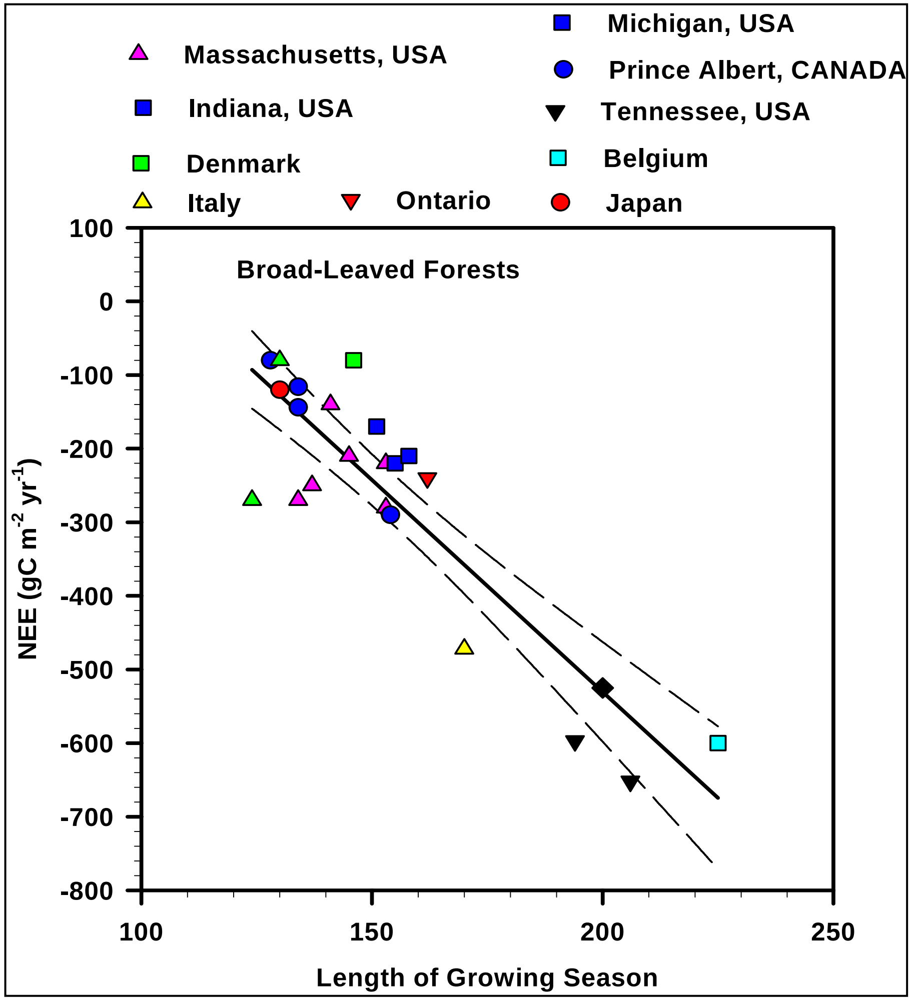
Schwartz and Reiter 2000
International. J. Climatology

ADAPTATION

Integration of spatially-extensive phenological data and models with both short and long-term climatic forecasts offer a powerful agent for human adaptation to ongoing and future climate change.

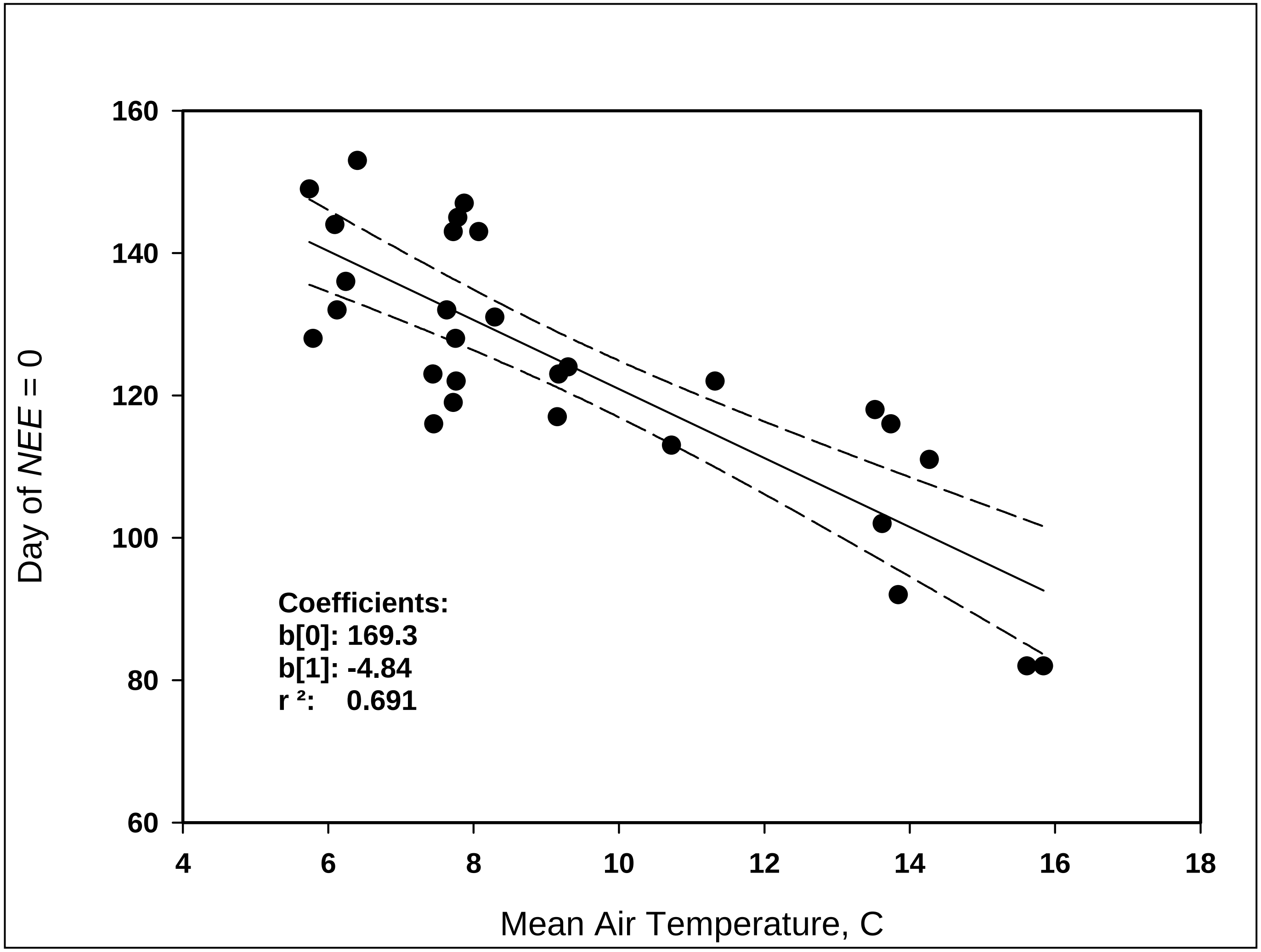
The predictive potential of phenology requires a new data resource—*a national network of integrated phenological observations and the tools to access and analyze them at multiple scales*.

Spatial Gradients:
NEE and Length of Growing Season



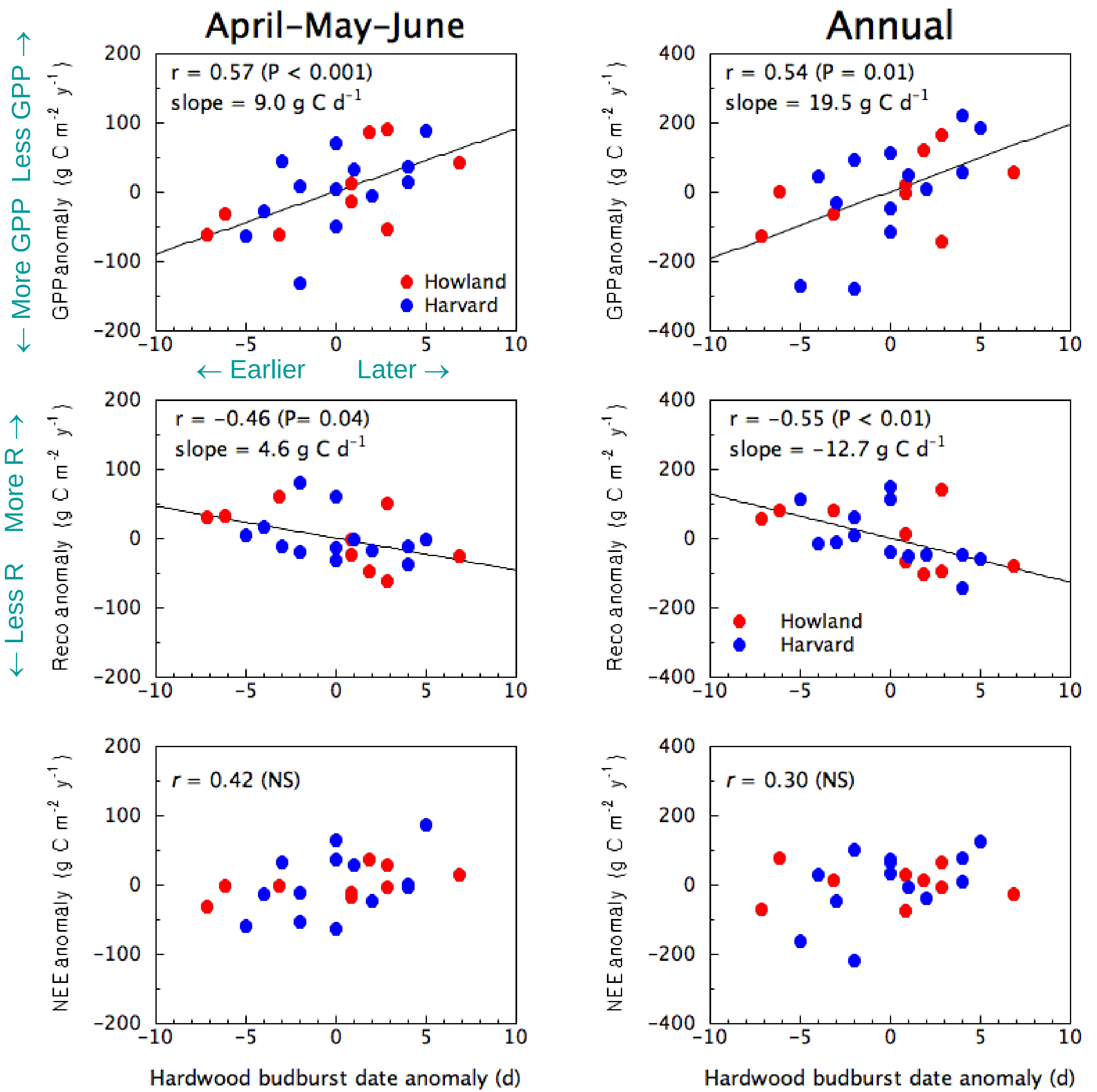
Baldocchi et al, 2001, BAMS

Onset of Spring is Delayed ~ 5 days with each degree reduction in mean temperature



Baldocchi et al. Int J. Biomet, 2005

Variation in bud-burst phenology



Offsetting variation in Reco and GPP.

Annual effect = twice as large as spring effect.

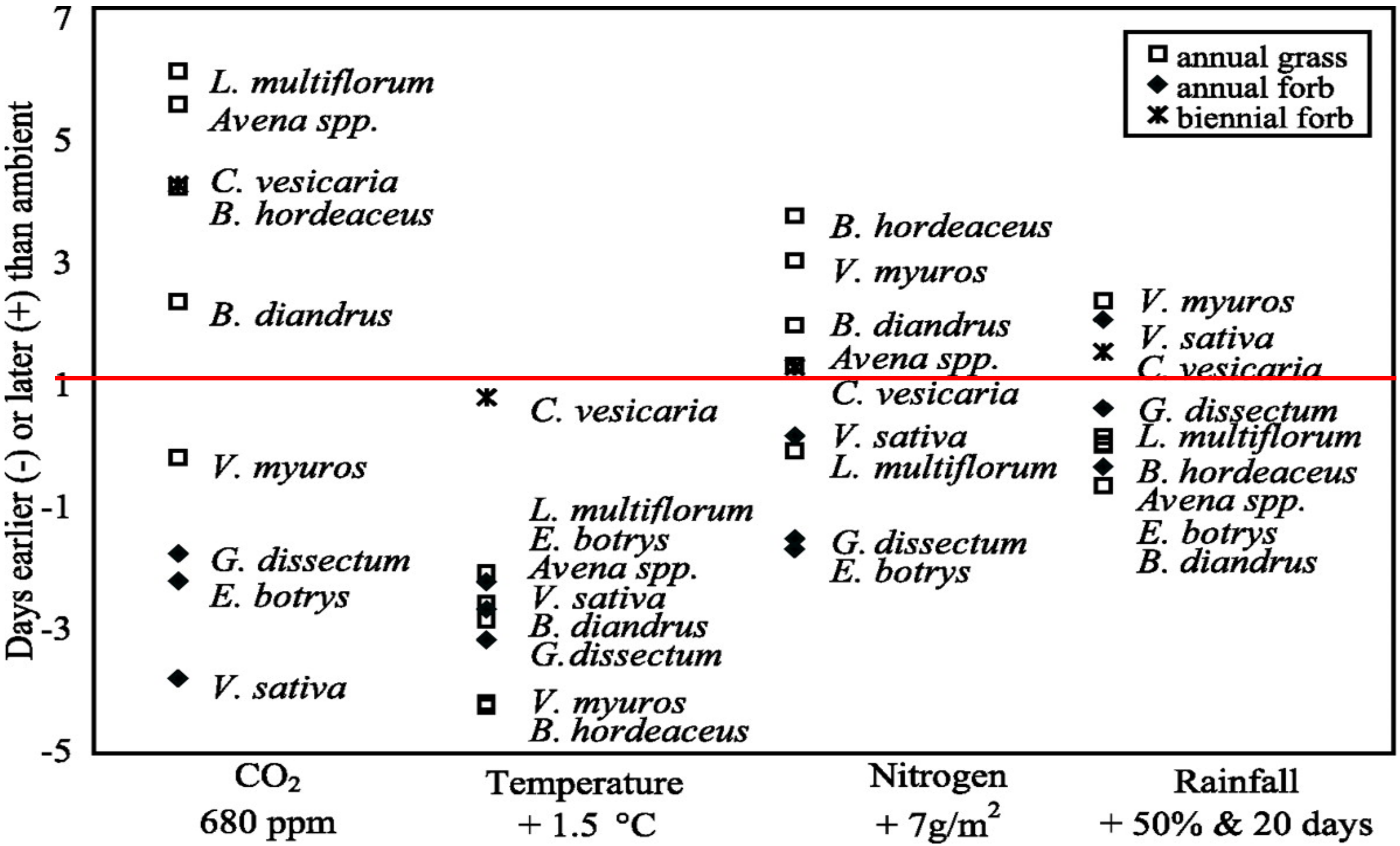
Possibility of lagged effects.

Results *do not differ significantly between hardwood and conifer forest*.

Andrew Richardson

SYNCHRONEITY

Species/functional groups respond differentially to different global change drivers

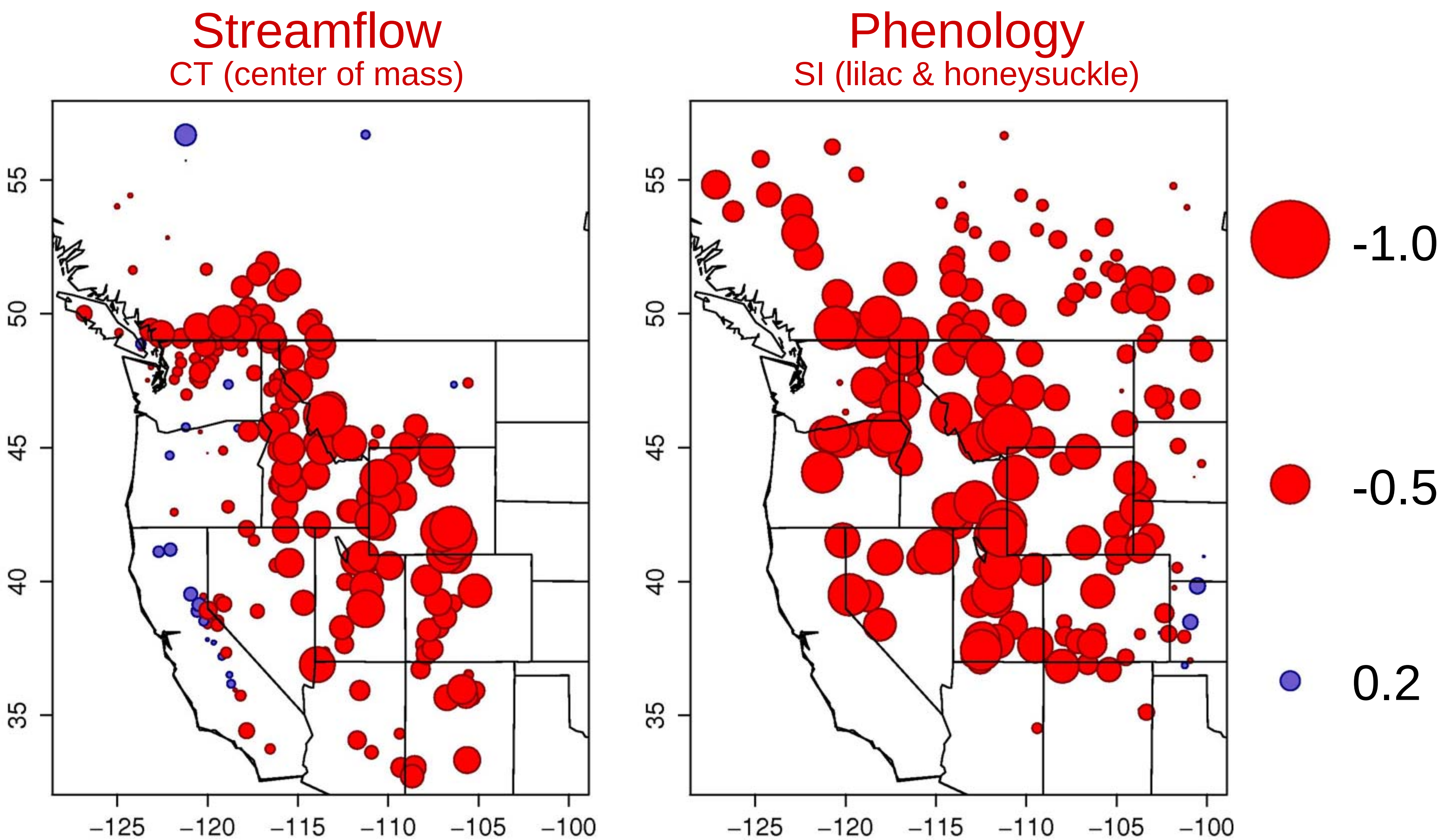


Cleland et al. 2006 PNAS

Predicting frequency of large forest fires

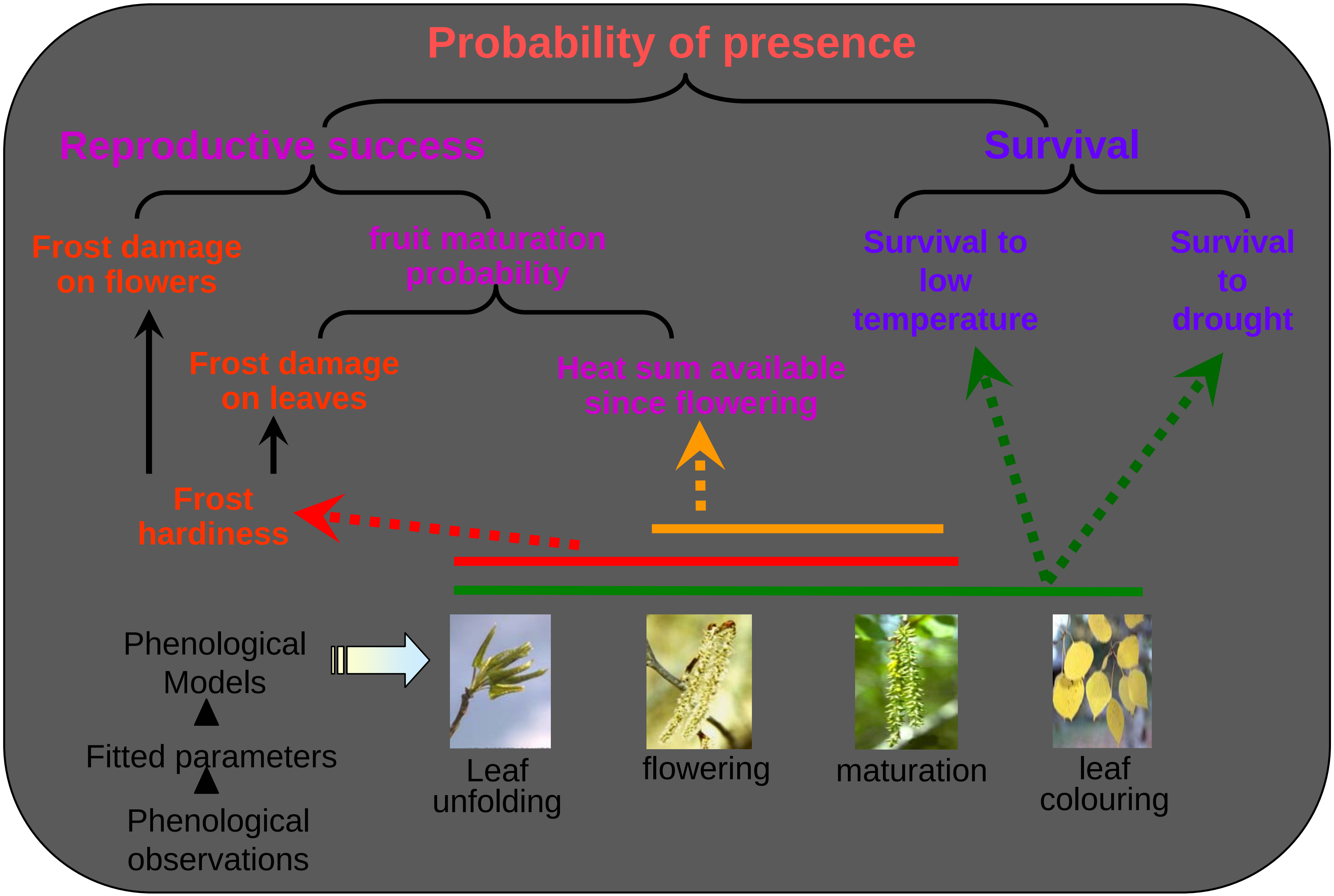
fires > 400 ha in SW US, 1970-2003, vs CT and vs SI

(Phenology does a better job of predicting fire occurrence)



Westerling, Schwartz & Betancourt, in prep.

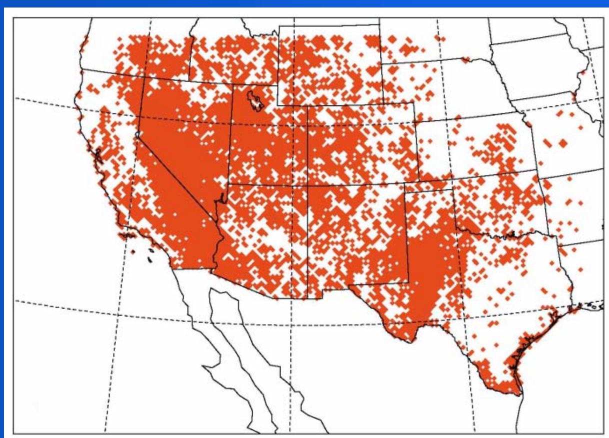
PHENOFIT



Chuine & Beaubien 2001, Morin & Chuine 2005)

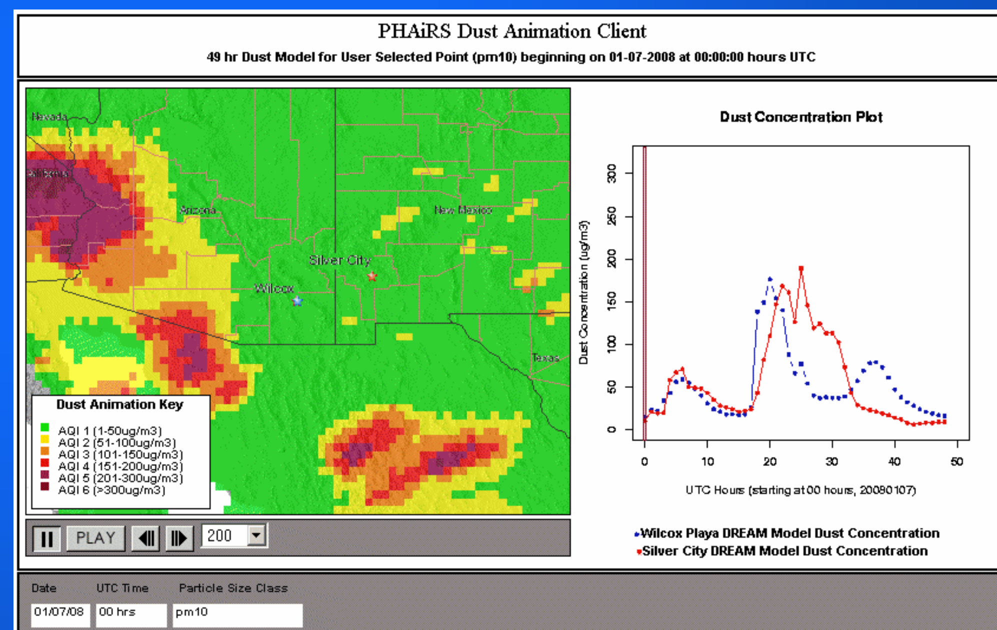
Phenology and Pollen Transport

NASA Remote Sensing



Currently – dust source regions
Future – pollen sources derived from **phenological** maps

DREAM – UofA numerical meteorological particulate transport model



Final Product – predicted concentrations of pollen in time and space

http://www.atmo.arizona.edu/research/dust/dust.html

What observations, models and tools do we need to adapt to longer, hotter growing seasons?

Workshop Task?

Considerations:

TOOLS …

- Phenology observations at instrumented and frequented research sites
  (Inexpensive, “no-regrets” approach)

- Dendro-Phenology

- Processes derived from Networks of Flux Measurement Sites can be Transformed onto Climate Space to produce Phenology Maps

- New Technologies for monitoring Phenology
  - Eddy Flux, $$$$
  - Digital Camera, $$
  - LED, NDVI/PRI Sensor, $

… to INFORM MODEL DEVLOPMENT, CARE and FEEDING

- Phenology-driven; i. e. PHENOFIT, Pollen dispersion