such as drought, insect breeding, or pathogenic blue stain fungi. Such inciting factors affected the physiological functioning of the pine and reduced its potential for pathogen defense. Finally, the pine's death depended on further contributing factors such as secondary opportunistic insects and pathogenic fungi and nematodes, which killed the stressed pines. As most of these investigated factors are directly linked with increasing temperatures, the observed pine dieback will increase in abundance with unknown consequences for forest goods and services.

**Population-wide mortality in multiple forest types in western North America: onset, extent, and severity of impacts as indicators of climatic influence.** Shaw, J.D. (*U.S. Forest Service, USA; jdshaw@fs.fed.us*), Long, J.N. (*Utah State University, USA; james.long@usu.edu*), Thompson, M.T. (*U.S. Forest Service, USA; mtthompson@fs.fed.us*), DeRose, R.J. (*Utah State University, USA; rjustinderose@gmail.com*).

A complex of drought, insects, and disease is causing widespread mortality in multiple forest types across western North America. These forest types range from dry *Pinus-Juniperus* woodlands to moist, montane *Picea-Abies* forests. Although large-scale mortality events are known from the past and considered part of natural cycles, recent events have largely been attributed to climate change. We use data from the Forest Inventory and Analysis program to assess the onset, extent, and severity of impacts of mortality events that have occurred since the mid-1990s. We examine progression of mortality from susceptible stand structures to less susceptible conditions, large-scale patterns within forest types as related to elevation and latitude, and the sequence of mortality onset among different forest types located along topo-edaphic gradients. We found that there have been synchronous insect outbreaks over millions of hectares, suggesting that broad-scale climatic factors are involved. However, at this point it does not appear that there have been significant range contractions such as might be expected from shifting climatic conditions, and local extirpations have been rare. Our current research includes improvement of methods we use to analyze mortality trends, so that population shifts can be detected when they occur.

**Widespread increase of tree mortality rates in the western United States.** Van Mantgem, P., Stephenson, N.L. (*U.S. Geological Survey, USA; pvanmantgem@usgs.gov; nstephenson@usgs.gov*), Byrne, J.C. (*U.S. Forest Service, USA; jbyrne@fs.fed.us*), Daniels, L.D. (*University of British Columbia, Canada; daniels@geog.ubc.ca*), Franklin, J.F. (*University of Washington, USA; jff@u.washington.edu*), Fulé, P.Z. (*Northern Arizona University, USA; Pete.Fule@nau.edu*), Harmon, M.E. (*Oregon State University, USA; Mark.Harmon@oregonstate.edu*), Larson, A.J. (*University of Montana, USA; andrew.larson@cfc.umt.edu*), McDowell, N. (*Los Alamos National Laboratory, USA; mcdowell@lanl.gov*), Smith, J.M. (*University of Colorado, USA; jmsmith@colorado.edu*), Taylor, A.H. (*Pennsylvania State University, USA; aht1@psu.edu*), Veblen, T.T. (*University of Colorado, USA; veblen@colorado.edu*).

Persistent changes in tree mortality rates can alter forest structure, composition, and ecosystem services such as carbon sequestration. Our analyses of longitudinal data from unmanaged old forests in the western United States showed that background (non-catastrophic) mortality rates have increased rapidly in recent decades, with doubling periods ranging from 17 to 29 years among regions. Increases were also pervasive across elevations, tree sizes, dominant genera, and past fire histories. Forest density and basal area declined slightly, suggesting that increasing mortality was not caused by endogenous increases in competition. Regional warming and consequent increases in water deficits are likely contributors to the increases in tree mortality rates. Increasing mortality rates in some cases could be symptomatic of forests that are stressed and vulnerable to abrupt die-back. We will present preliminary results from other work at our sites, including the reasons for declining forest basal area and patterns of tree-ring stable carbon isotopes from samples of living and recently dead trees, which provide evidence about the causes of mortality. Our work contributes to a growing body of evidence indicating that ongoing environmental changes may be driving both chronic and acute changes in forests worldwide.

**Climate change impact on tree architecture may contribute to forest decline and dieback.** Vennetier, M., Girard, F. (*CEMAGREF, France; michel.vennetier@cemagref.fr; francois.girard@cemagref.fr*), Ouarmim, S. (*CNRS, France; samira.ouarmim@cefe.cnrs.fr*), Thabeet, A. (*University of Alep, Syria; alithabt@yahoo.fr*), Ripert, C. (*CEMAGREF, France; christian.ripert@cemagref.fr*), Caraglio, Y. (*CIRAD, France; yves.caraglio@cirad.fr*), Cailleret, M. (*INRA, France; maxime.caillert@avignon.inra.fr*).

The impact of repeated droughts on tree architecture was studied in south-eastern France from 1995 to 2010. For all six studied species, branching rate decreased and for concerned species, a reduction of polycyclism rate occurred. The size and number of leaves were also significantly reduced. The simplified architecture limits the capacity of trees to explore available space and contributes to low LAI and crown transparency. For evergreen species, reductions in leaf size also limit the potential maximum LAI for 3 to 8 years according to their life span. Together, changes in light architecture and leaf size may cut the potential LAI by more than 50% for several years after repeated bad years. This may contribute to carbon shortage and starvation for many years following extreme climatic events. For some species, long measurement series allowed untangling of the relationship between architecture parameters and climate parameters (monthly or seasonal) from current and previous years. The models showed that crown development should be significantly reduced in the future. Architectural parameters appeared to be directly linked to tree vigour, and could be good indicators of tree health. The simplification of architecture can be considered as an early warning of potential dieback.

**Chinese and global examples of drought and heat-induced forest mortality associated with insect pests and pathogens**. Zhang, Z. (*Research Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry, China; zhangzhen@caf.ac.cn*), Allen, C.D. (*U.S. Geological Survey, Jemez Mountains Field Station, USA; craig_allen@usgs.gov*).

Projected climate change increases in warm and dry conditions have potential to interact with biotic agents such as insect pests and diseases to markedly increase tree mortality in many regions. A recent global overview reported 88 documented examples of drought- and heat-induced tree mortality. Although quantitative comparisons among these highly diverse examples are subject to consistency and precision challenges due to the wide range of methods used in the original studies, along with variability in the amount of detail provided in the overview summary tables, it is observed that 56% (49 of 88) of these examples reported