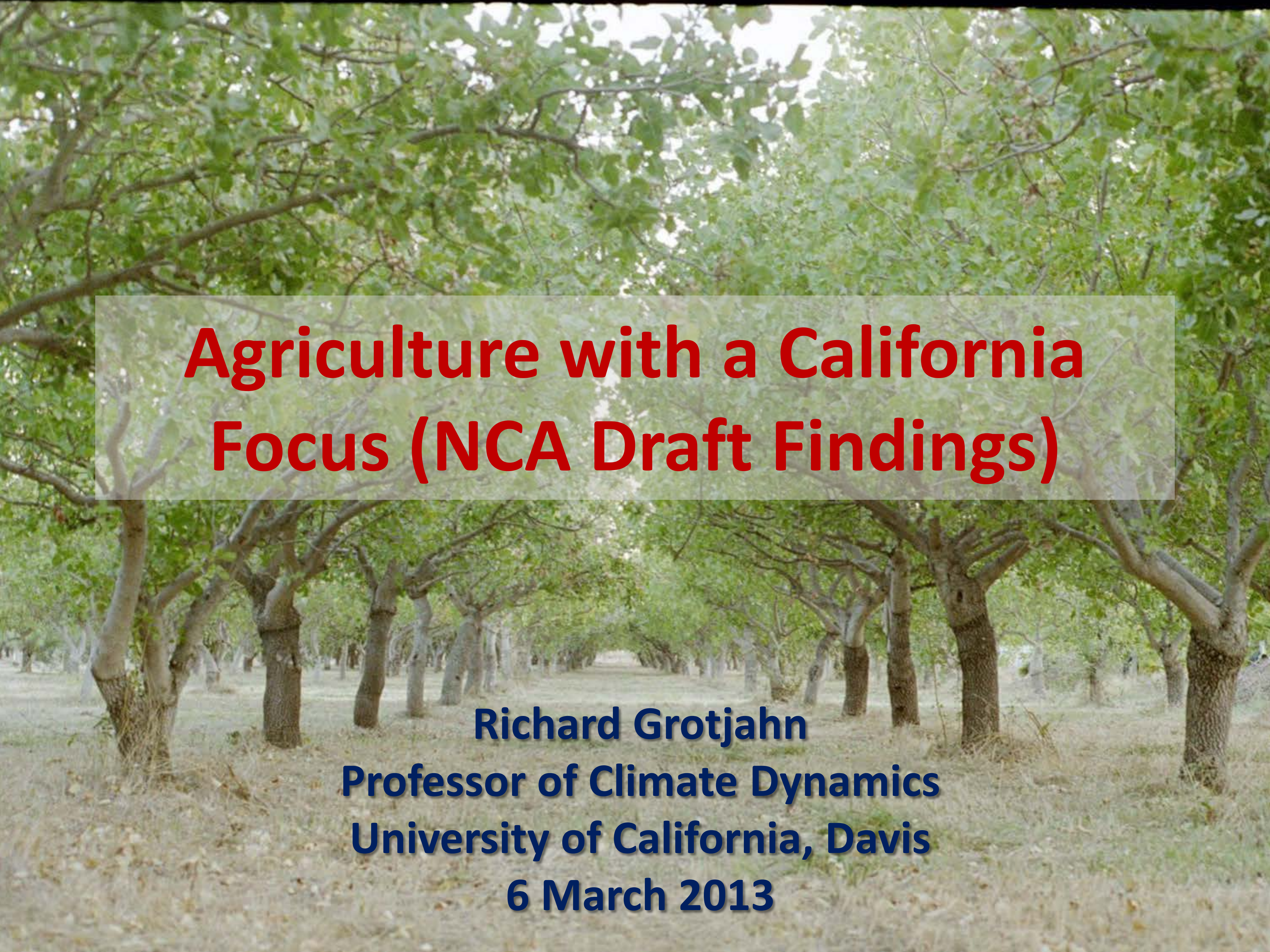


Agriculture with a California Focus (NCA Draft Findings)

Richard Grotjahn
Professor of Climate Dynamics
University of California, Davis
6 March 2013

Authors of Chapter 6: Agriculture

- **Convening Lead Authors**
- Jerry Hatfield, U.S. Department of Agriculture
- Gene Takle, Iowa State University
- **Lead Authors**
- Richard Grotjahn, University of California, Davis
- David Gustafson, Monsanto
- Patrick Holden, Waterborne Environmental Inc.
- R. Cesar Izaurralde, U.S. Department of Energy, Pacific Northwest National Laboratory
- Terry Mader, University of Nebraska, Lincoln
- Elizabeth Marshall, U.S. Department of Agriculture

Outline

- 6 key messages (nationwide agriculture)
- Background
  - California agriculture (general)
  - Crop phenology
- Key issues for California agriculture (selected)
  1. CO_2
  2. High temperatures
  3. Chilling hours
  4. Water
  5. Extremes
  6. Adaptation
- Summary of key messages

Agriculture 'Key Messages' (Overview)

1. Climate disruptions to agricultural production have increased in the recent past and are projected to increase further over the next 25 years. By mid-century and beyond, these impacts will be increasingly negative on most crops and livestock.

2. Many agricultural regions will experience declines in crop and livestock production from increased stress due to weeds, diseases, insect pests, and other climate change-induced stresses.

3. Current loss and degradation of critical agricultural soil and water assets by increasing extremes in precipitation will continue to challenge both rain-fed and irrigated agriculture unless innovative conservation methods are practiced.

4. The rising incidence of weather extremes will have increasingly negative impacts on crop and livestock productivity because critical thresholds will be exceeded.

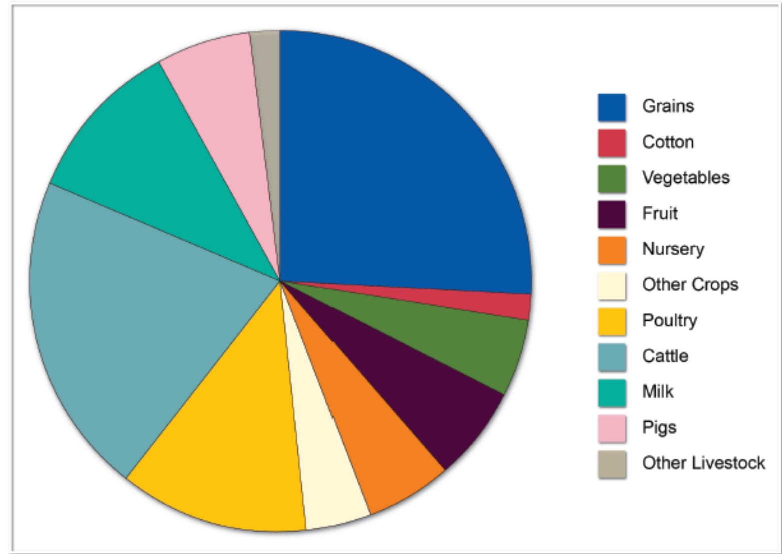
5. Agriculture has been able to adapt to recent changes in climate; however, increased innovation will be needed to ensure the rate of adaptation of agriculture and the associated socioeconomic system can keep pace with future climate change.

6. Climate change effects on agriculture will have consequences for food security both in the U.S. and globally, including not only changes in crop yields, but also changes in the ways climate affects food processing, storage, transportation, and retailing.

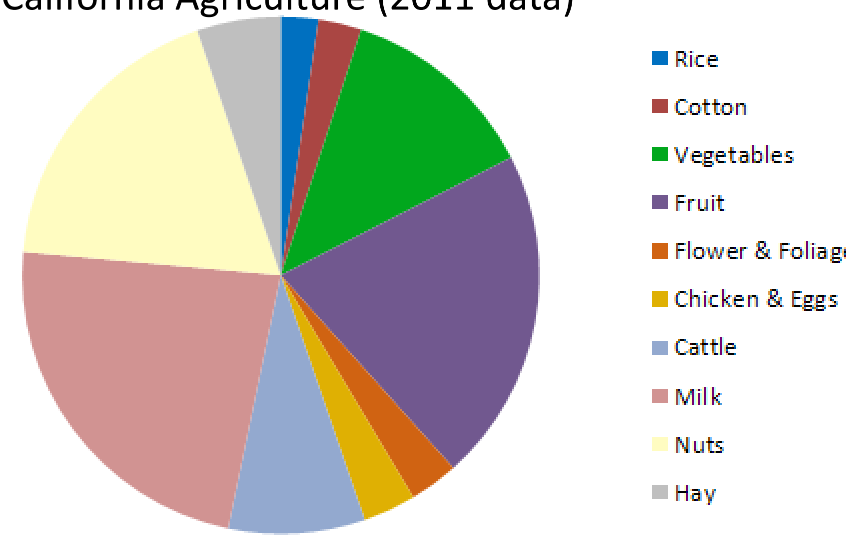
Commodities

- National mix
  - ½ animal commodities
  - ¼ grains.
- California has a different mix
  - Plot of top 20 sorted into commodities
  - ~ 1/3 animal (mostly dairy)
  - ~ 1/5 fruit
  - ~ 1/6 nuts

U.S. Agriculture



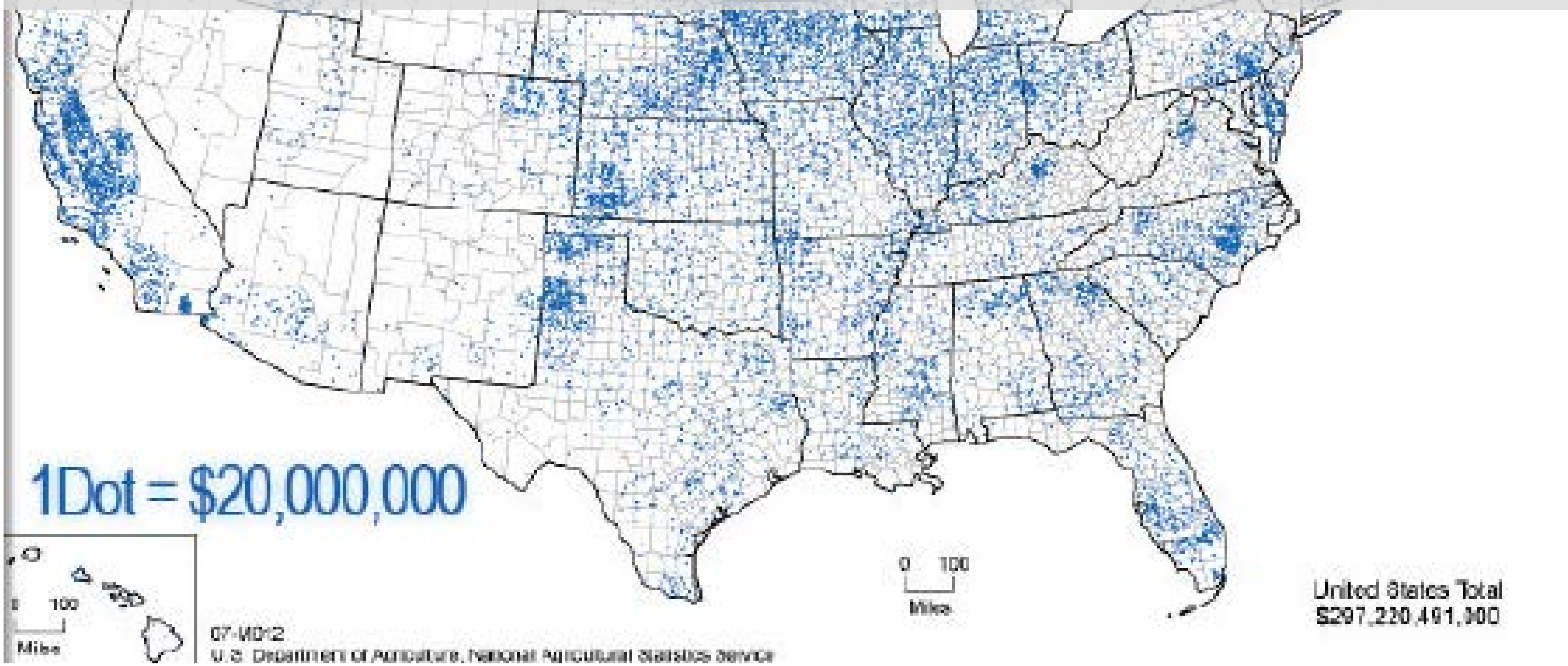
California Agriculture (2011 data)



Source: NASS/CDFA Agricultural Resource Report, 2012

California Agriculture (overview)

- **Highly diverse, >400 commodities**
- **$43.5B cash receipts (2011), 9 of top 10 counties in California**
- **64% (>$13B) of US production of tree fruits and nuts.**
- **Nationally 1st in many products:**
  - **Dairy, Greenhouse & nursery, Grapes, Almonds, Lettuce, Strawberries, Tomatoes, Walnuts, Cole crops, Carrots, Lemons, Celery, Peaches, Raspberries, Plums and Prunes and 65 other crops.**
- **Nationally 2nd largest :**
  - **rice producer (after Arkansas) and citrus (after FL)**
- **8.7 M ac of irrigated farmland (8 M ac irrigated during 2007 drought)**



Phenologic Quantities (crops)

- Developmental temperature thresholds
  - Lower = T below which development stops. E.g. 9.4C (49F) for citrus flower.
  - Related: Mortality threshold (plant or animal dies)
  - Upper = T above which growth rate decreases (animals also affected)
- Physiological time
  - Combination of degrees and time above (or below) a threshold. 2 deg above threshold for 2 hours same as 1 deg above for 4 hours.
  - Amount of heat needed to fully develop (e.g. growing degree hours)
  - Amount of chilling needed to fully develop (chilling hours)
- Chilling hours are cumulative hours…
  - Below 45F, or
  - Between 32F and 45F
  - During 1 November through end of February (in CA).
  - Needed for sufficient dormancy for adequate dormancy break

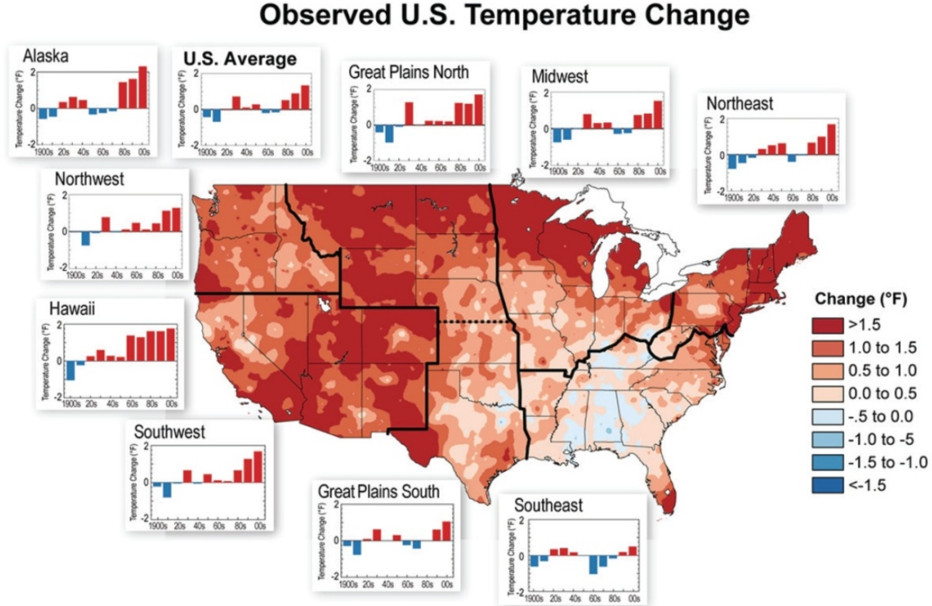
1. Elevated CO_2 Effects

- Can increase plant growth and water use efficiency
- However,
  - Rising T increases water demand offsetting efficiency gain
  - Impacts on grain and fruit yields mixed
  - N and protein content reduced in alfalfa (forage quality decline)
  - Other stressors present. Example: several weed species even more stimulated than crop
  - Interaction with temperature and water changes not well understood

2a. Temperature

- Projections vary as to temperature over California.
- Recent historical trend 0.5-1 F increase.
- Future projection is 2-7 F
- Feedback between dry soils/drought affected vegetation and higher heat
- Even most optimistic scenario has warming

Fig 2.6: Observed change 1991-2011 vs 1901-1921



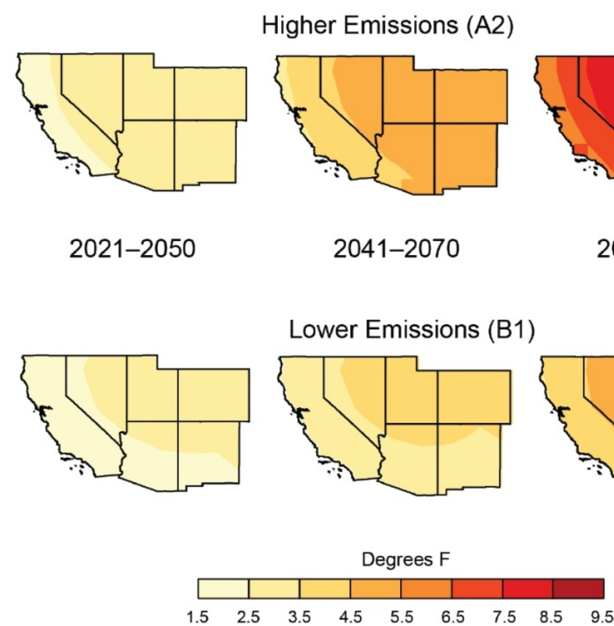


Fig 20.1

2b. High Temperature Effects

- High T reduce crop yields.
- Cultivated plants grow too quickly
- High nighttime T reduce productivity during grain filling and fruit sizing
- Vegetables exceeding optimal range by 1.8-7.2 F moderately reduces yield; exceeding by 9-12.6 F leads to severe or total losses.
- Livestock can adjust to higher temperatures up to a point, but fertility, milk, egg production declines
- Livestock, crops have increased water demand (but supply limited or lessened)
- Combined with higher humidity pest pressures can increase

2c. High T on some CV Crops

- Crop models simulations for two emission scenarios
- Assumes crop nutrients maintained at adequate levels
- Yield changes as difference from 2000 baseline
- Yield varies among crops:
  - Alfafa no clear change
  - Rice and tomato show yield decline in second half of century
  - Cotton, maize, wheat, sunflower decline from early in century

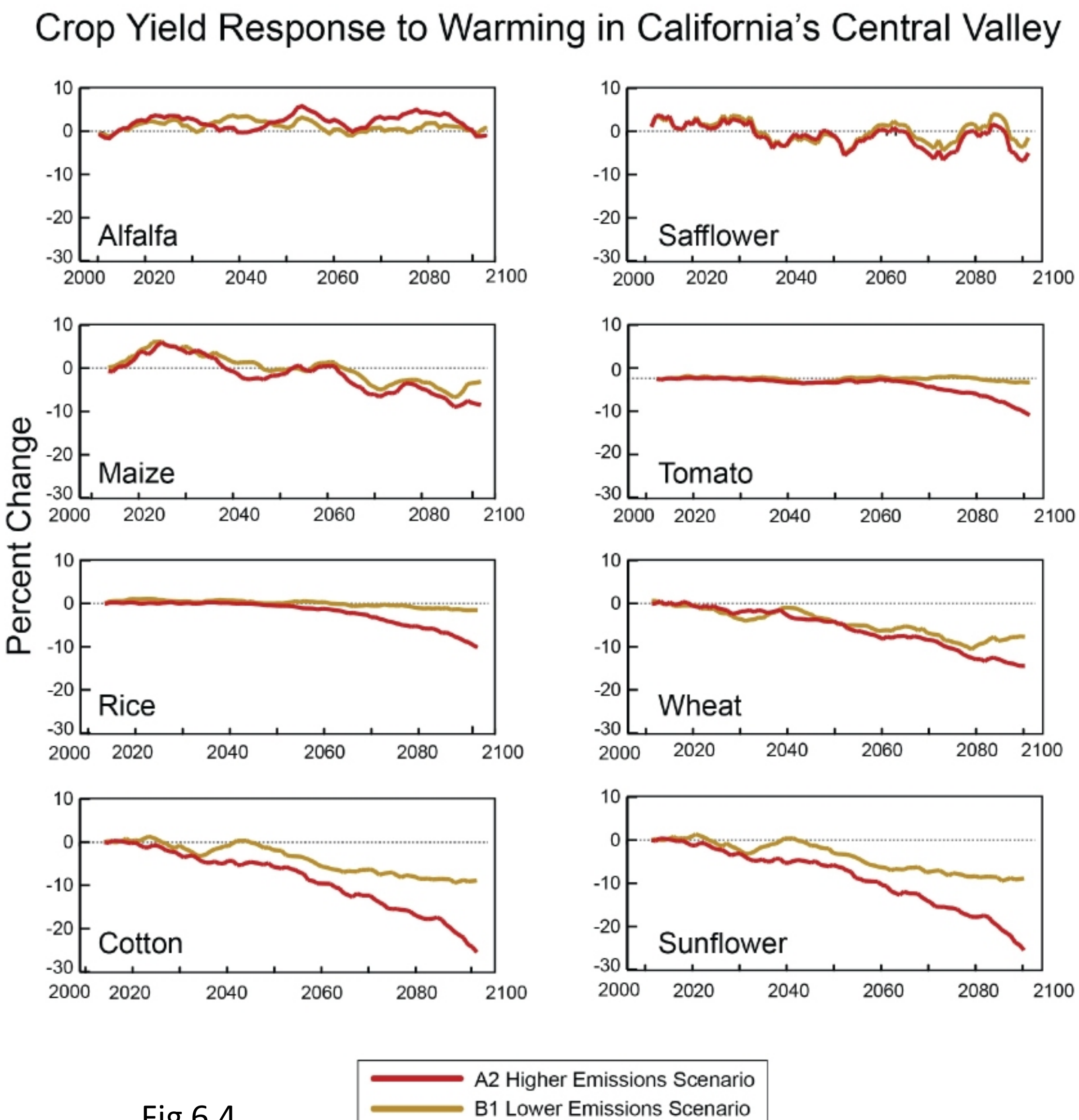
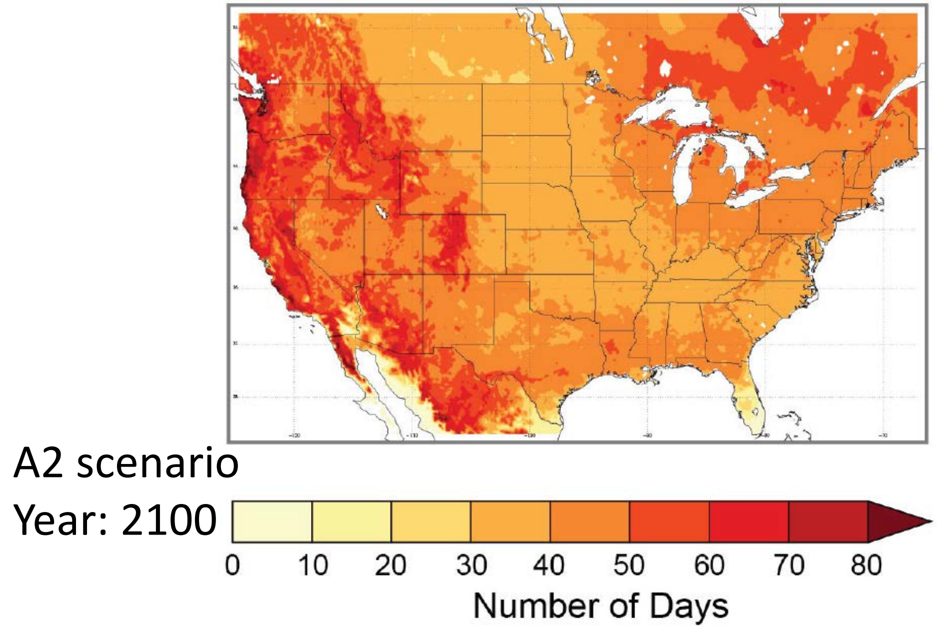


Fig 6.4

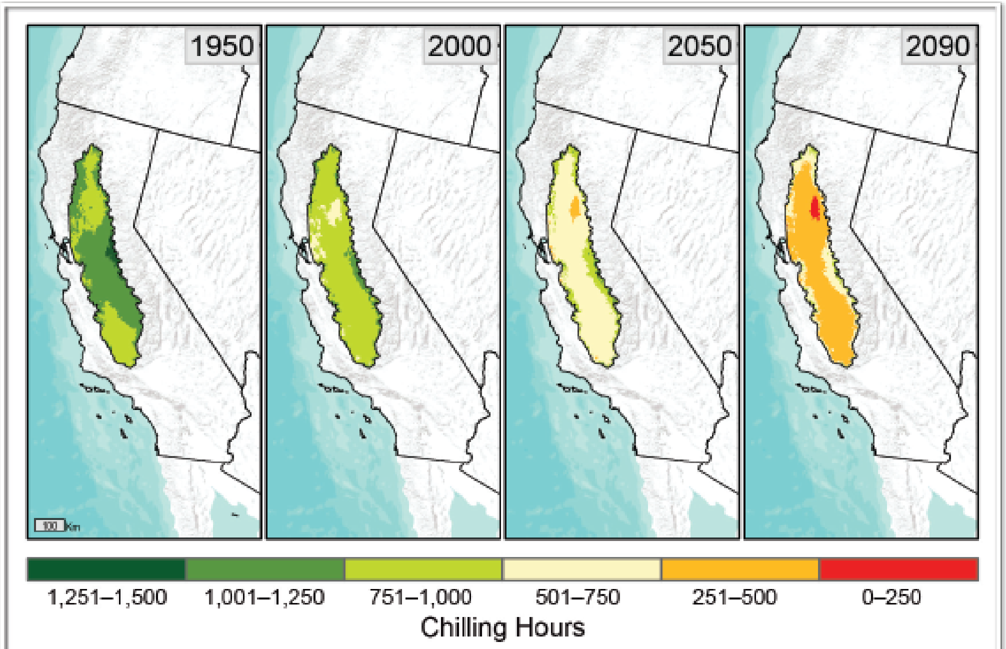
3. Chilling hours

- Frost free growing period expands
- Chilling hours needed for plant dormancy and bud development
- Warm winters cause earlier bloom and more frost vulnerability
- Tree crops* needing more than 750hrs:
  – Pistachios, peaches, nectarines
- Crops* needing more than 500hrs:
  – Walnut, European pear, kiwi
- *Lower chill varieties exist

Change in Frost-free Season Length



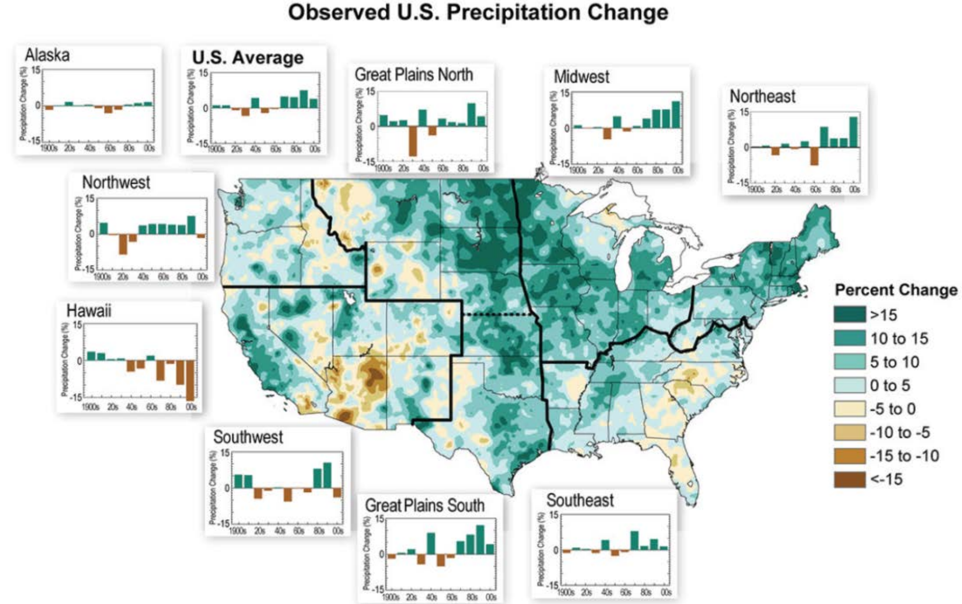
Many Plants Need Chilling to Produce Fruit — Reduced Chilling is Projected



4a. Precipitation

- Projections vary as to winter precipitation over California.
- Recent historical trends are mixed with possible increase.
- Future winter projections show a possible increase
- Future spring projections show possible decrease

Fig 2.11: Observed change 1991-2011 vs 1901-1921



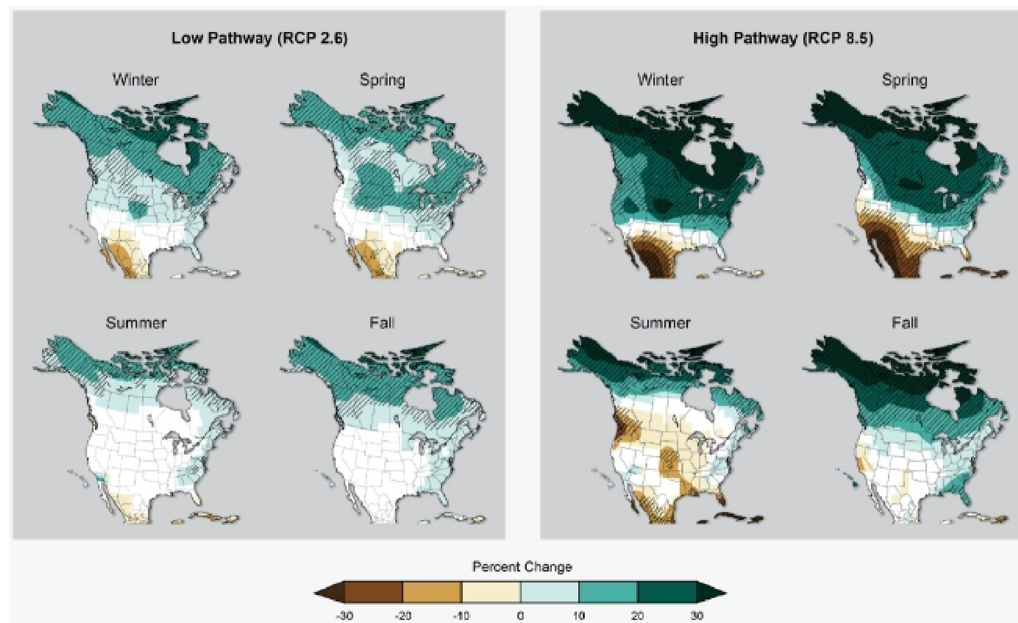


Fig 2.13: Projected 2071-2099 vs 1901-1960

4b. Irrigation

- Much agriculture is irrigated: by surface water delivery and from wells.
- Agriculture is a major consumer of freshwater
- Storage is behind dams and mainly in snowpack
- Snowpack projected to decline, decreasing flowing surface water.
- For CV rivers, more winter flow but less in the spring so annual total similar
- For the Colorado river, uncertain change in winter but less in the spring for annual reduction

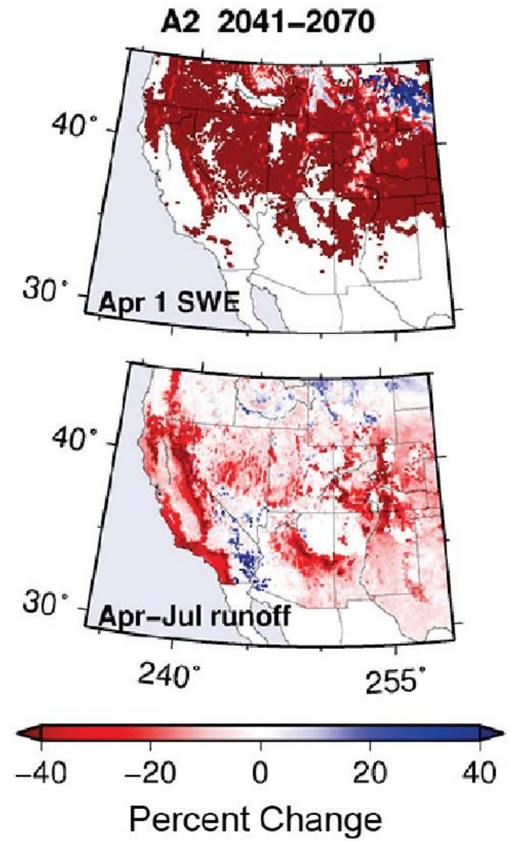
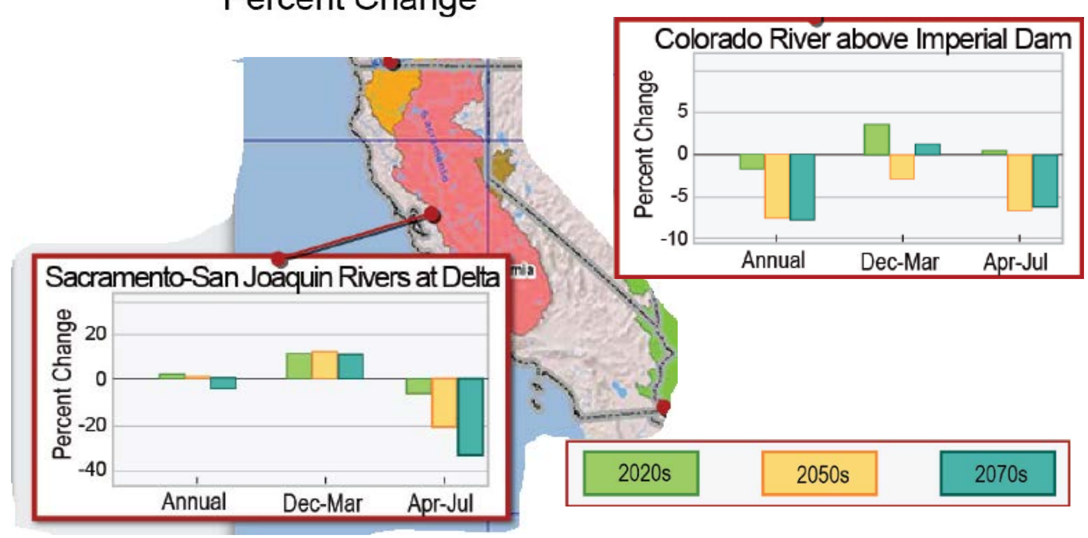


Fig 3.1: SWE: snow water Equivalent

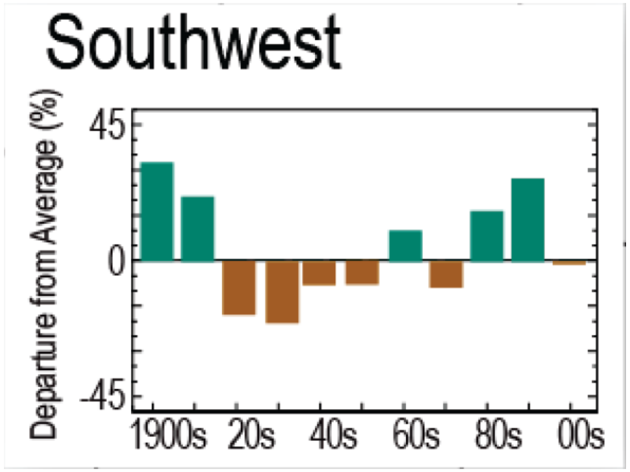
Fig 3.2: Projected seasonal flows



5a. Extremes (P)

- annual amount of precipitation that falls as very heavy precipitation (top 1% of daily events)
- Observed trend over Southwest unclear. Some evidence for increasing fraction.
- Projected increase in frequency of once in 20 year events.
- Plotted as multiplier w.r.t. event that happened once in the 1981-2000 period
- Events could occur 2 to 4 times as often
- Flooding, erosion are concerns

Fig 2.15: Observed change 1991-2011 vs 1901-1921



Rare Heavy Precipitation Events Become More Common

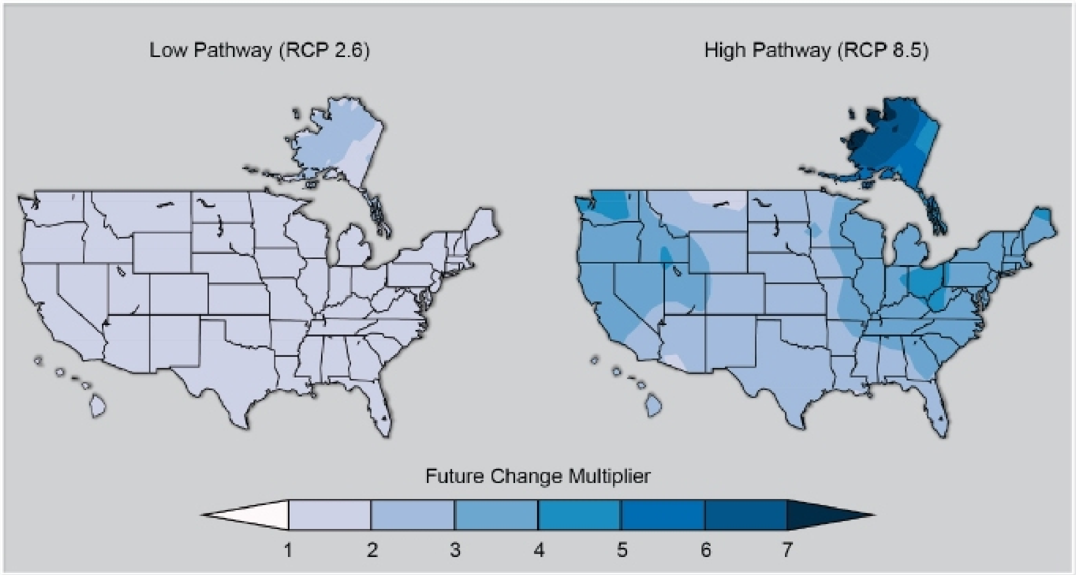
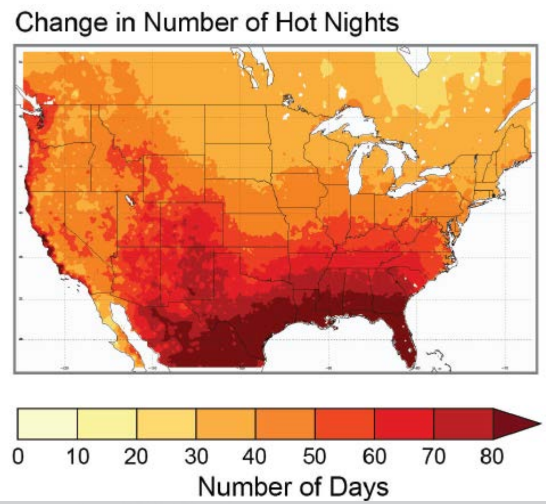


Fig 2.17 multiplier on historical 1 in 20 year events

5b. Extremes (T)

- Elevated night temperature
  - reduce recovery from hot daytime
  - Projected to increase
- Temperature of hottest and coldest days projected to increase
  - 3-9 F for coldest
  - 2-10 F for hottest
  - Even most optimistic scenario (RCP 2.6) has warming
- Dairy production more affected by number of days of extreme heat. Meat, egg production also reduced
- Crops, animals have fixed thresholds, these may be exceeded more frequently
- Fruit & vegetables have high water content, visual appearance reduced

Fig 6.5d Days in 2100 with T_{min} > 90% of T_{min} during 1971-1990



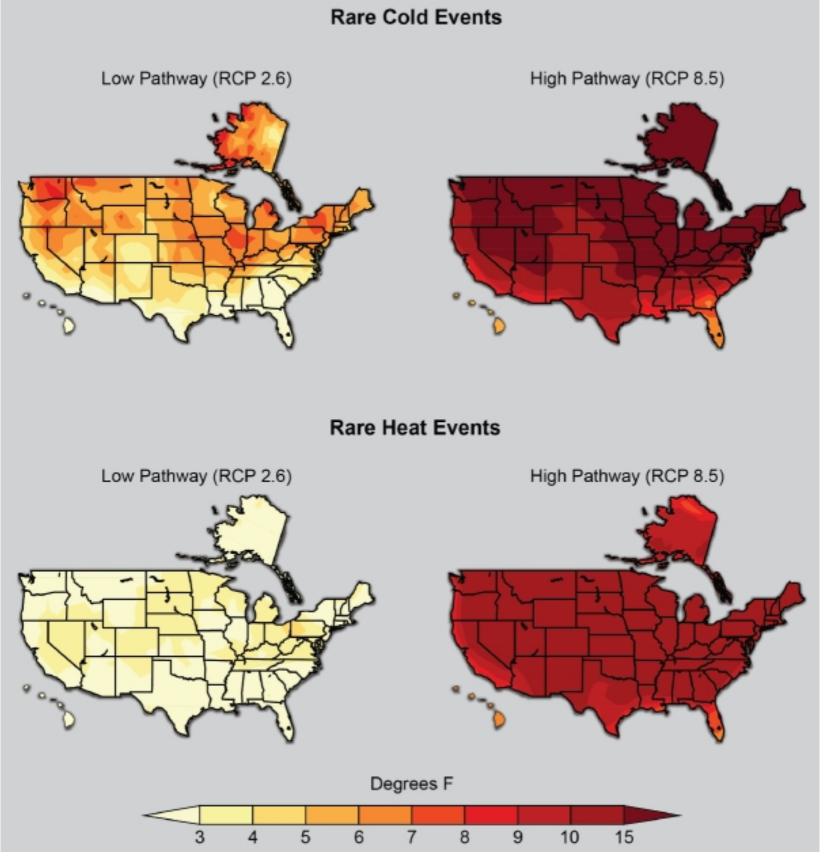


Fig 2.19 relative change of T for coldest & hottest 5% of events: 2081-2100 vs 1981-2000

6. Adaptation

- Offset high heat with additional water
  - Cooling of animals; delivered for transpiring plants
- Strategies include:
  - New varieties, chemical manipulation for lower chilling hours
  - Changing selection of crops & rotation
  - Timing of field operations & irrigation
  - Increased response to increased pest pressure
  - Technological innovation (e.g. drip vs furrow irrigation)
- ‘Climate risk’ management
  - more frequent, more intense events
  - market fluctuations from export/imports

Summary: California messages (1 of 2)

1. CO_2 affects
   - Vary with crop, may increase plant growth
   - Possible water efficiency increase but more water used to offset higher T
   - Quality may change adversely,
   - Some weed species even more amplified than crops
   - Elevated CO_2 in combination with T, humidity, nutrients unclear
2. Increasing temperature (T)
   - 0.5-1.5 F already. 2-7 F projected by 2100
   - Crops have temperature ranges, critical thresholds.
   - Impact varies with crop. low sensitivity (alfalfa), high (wheat, maize, sunflower), intermediate (rice, tomatoes) -- given adequate water & nutrients
   - Animals have optimal combinations of T and humidity. Elevating one or both reduces production and conception, increases mortality.
   - Increased pest pressure
3. Chilling hours
   - Projected to decline by half
   - Projected to dip below level needed for some tree crops

Summary: California messages (2 of 2)

4. Precipitation changes
   - Projected increase in winter (most areas), decrease in spring precipitation
   - Less snowpack – lost storage across seasons
   - Changes may reduce surface water available for irrigation
   - Erosion from increased extreme precipitation
5. Extreme events
   - Coldest and hottest events become warmer (2-9 F)
   - Have lasting impacts
   - Higher impact at key periods of plant sensitivity
6. Adaptation
   - California crop diversity has potential for adaptation
   - Possible new varieties developed or introduced from other regions.
   - Uncertainty introduced by export/import markets.
   - Many factors affect resilience of agriculture to climate change: (water delivery, financial assistance, insurance programs, infrastructure, globalization)