Climate Change Primer for Central California

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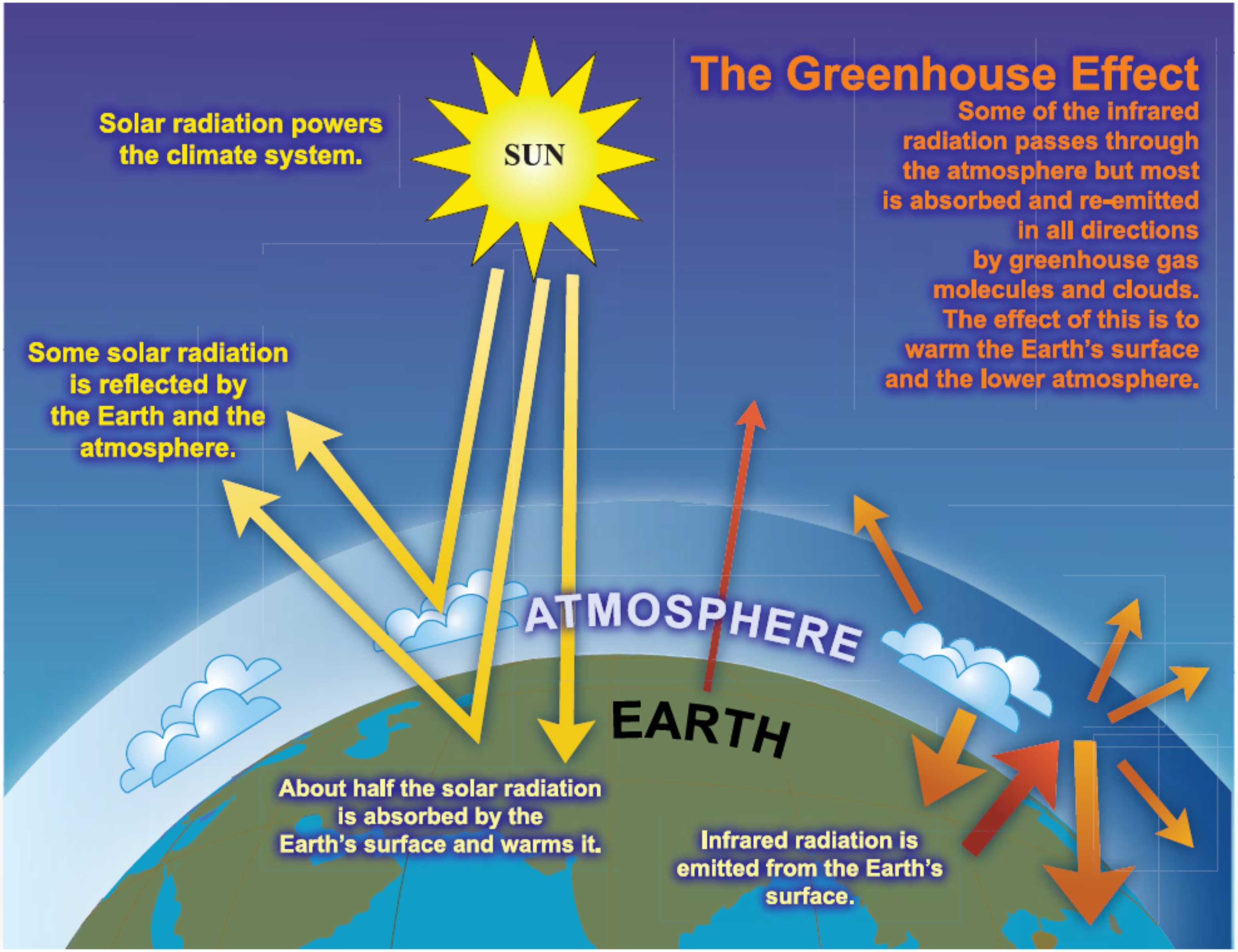

FAQ 1.3, Figure 1. *An idealised model of the natural greenhouse effect. See text for explanation.*

IPPC 4th Assessment Report 2007

Sources of Climate Change

- Global climate change due to increasing atmospheric temperatures
- Caused by increasing levels of carbon dioxide, methane and other gases (IPPC 4th Assessment 2007)
- Increased air temperatures affect many coastal processes

Increasing Air Temperatures

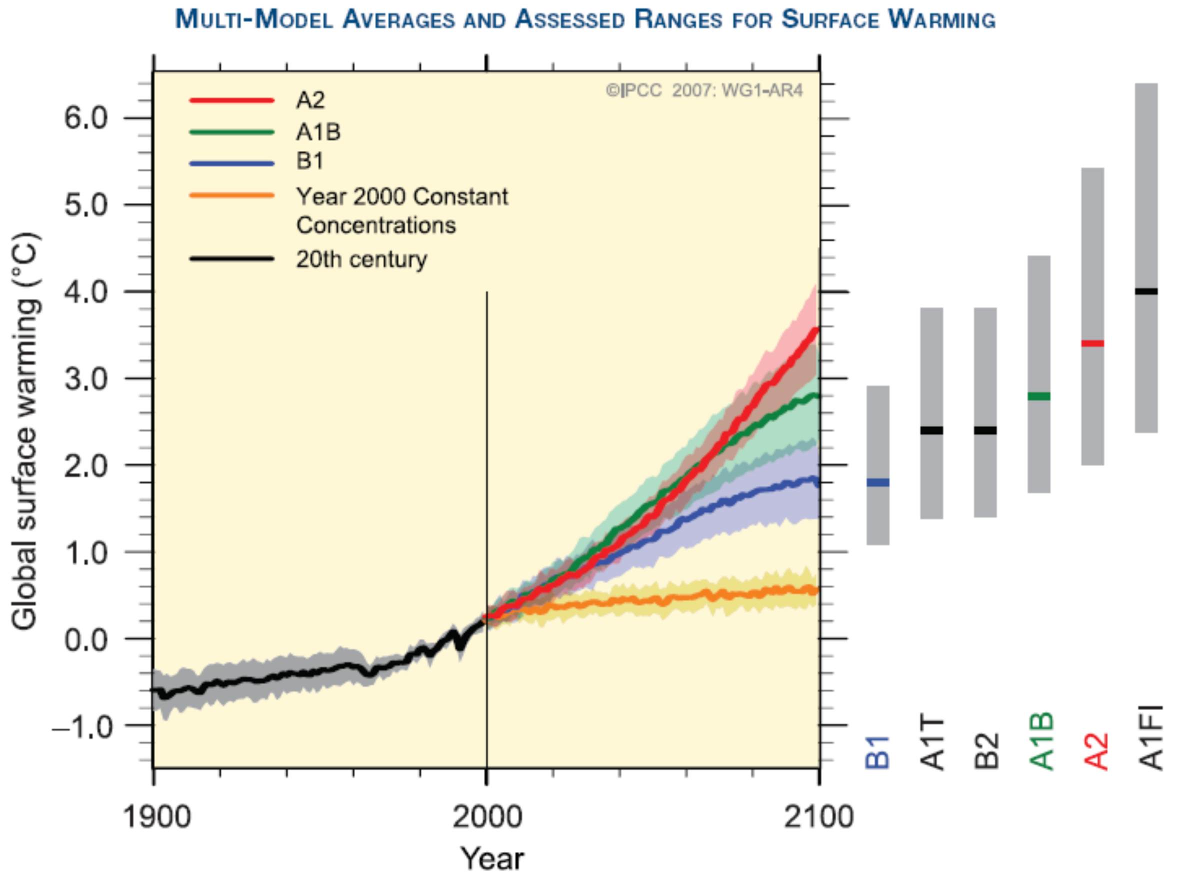

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* **likely** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* **likely** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

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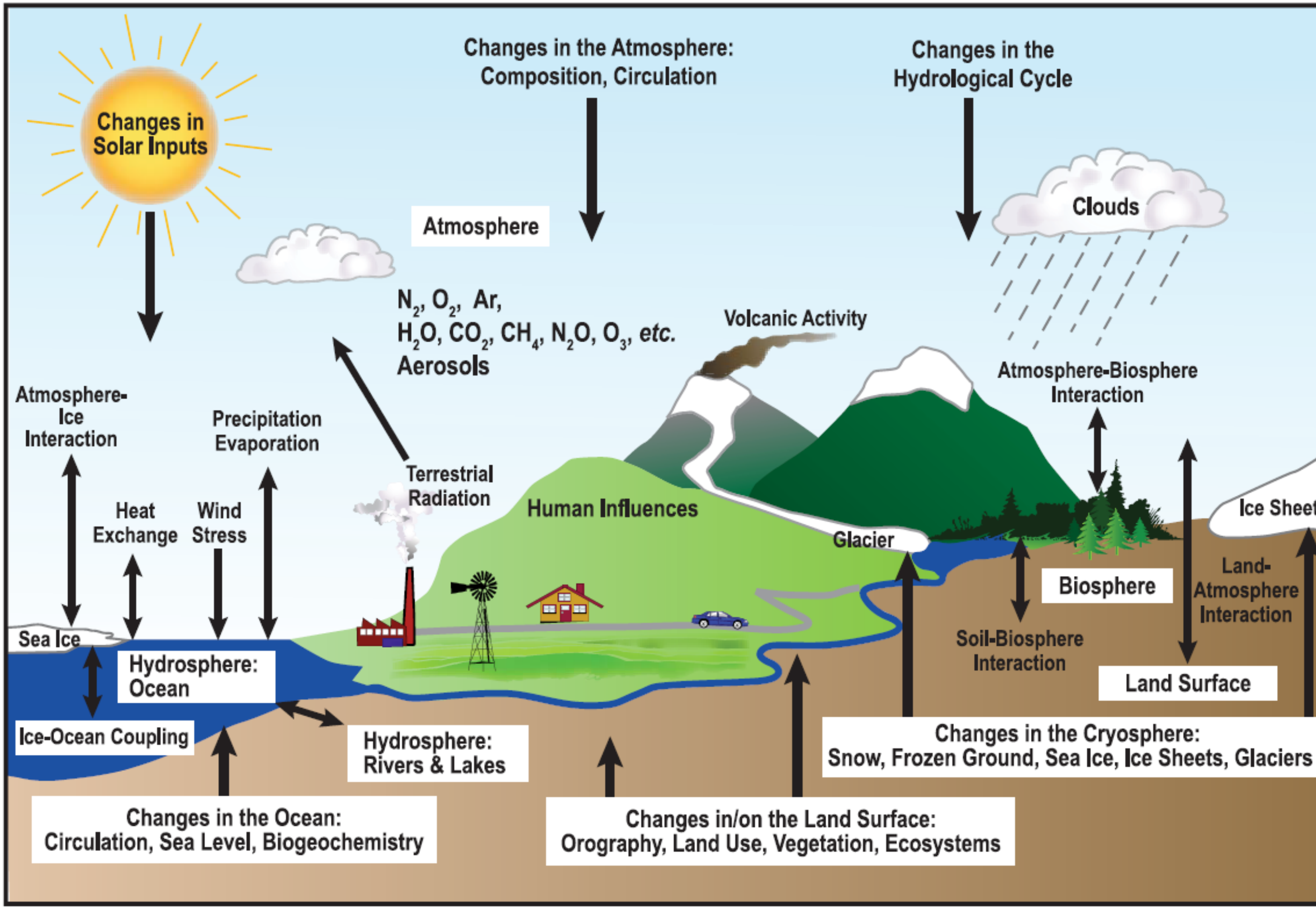

FAQ 1.2, Figure 1. *Schematic view of the components of the climate system, their processes and interactions.*

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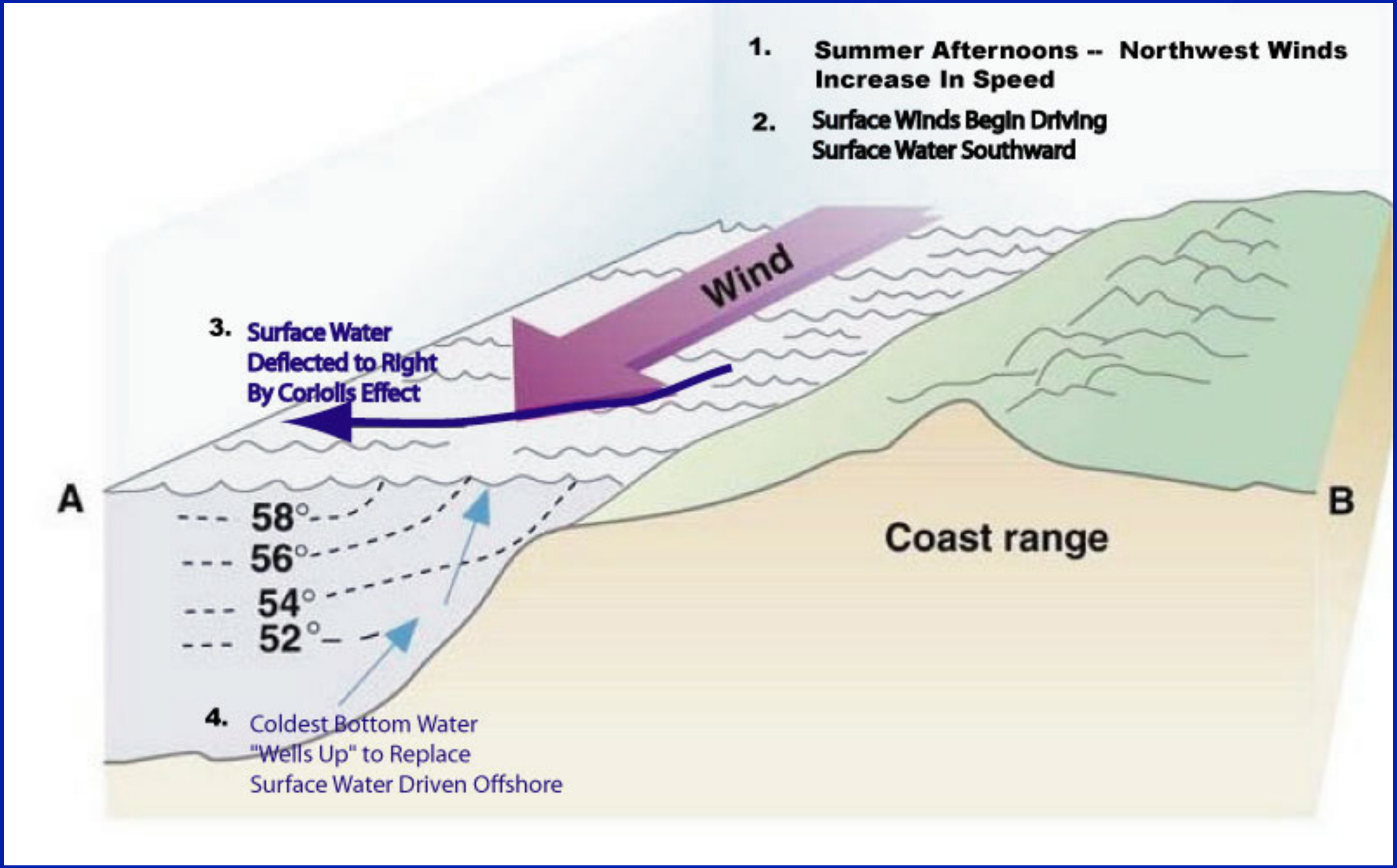
Global Models to Local Water Temperatures

- Primary models are global or regional scale models
- Understanding future conditions in local bays/estuaries requires ‘downscaling’ from larger scale models
- Models provide air temperature data
- Need wind and current information to project water temperatures

Increased Upwelling



Increased Coastal Upwelling

- Alongshore winds will increase
- Increasing along shore winds will increase depth and magnitude of upwelling
- Upwelling zone will have colder and nutrient rich water
- Shallow bays/estuaries will be warmer and more stratified
- Increasingly likelihood of low DO events

Increased Variability in Precipitation

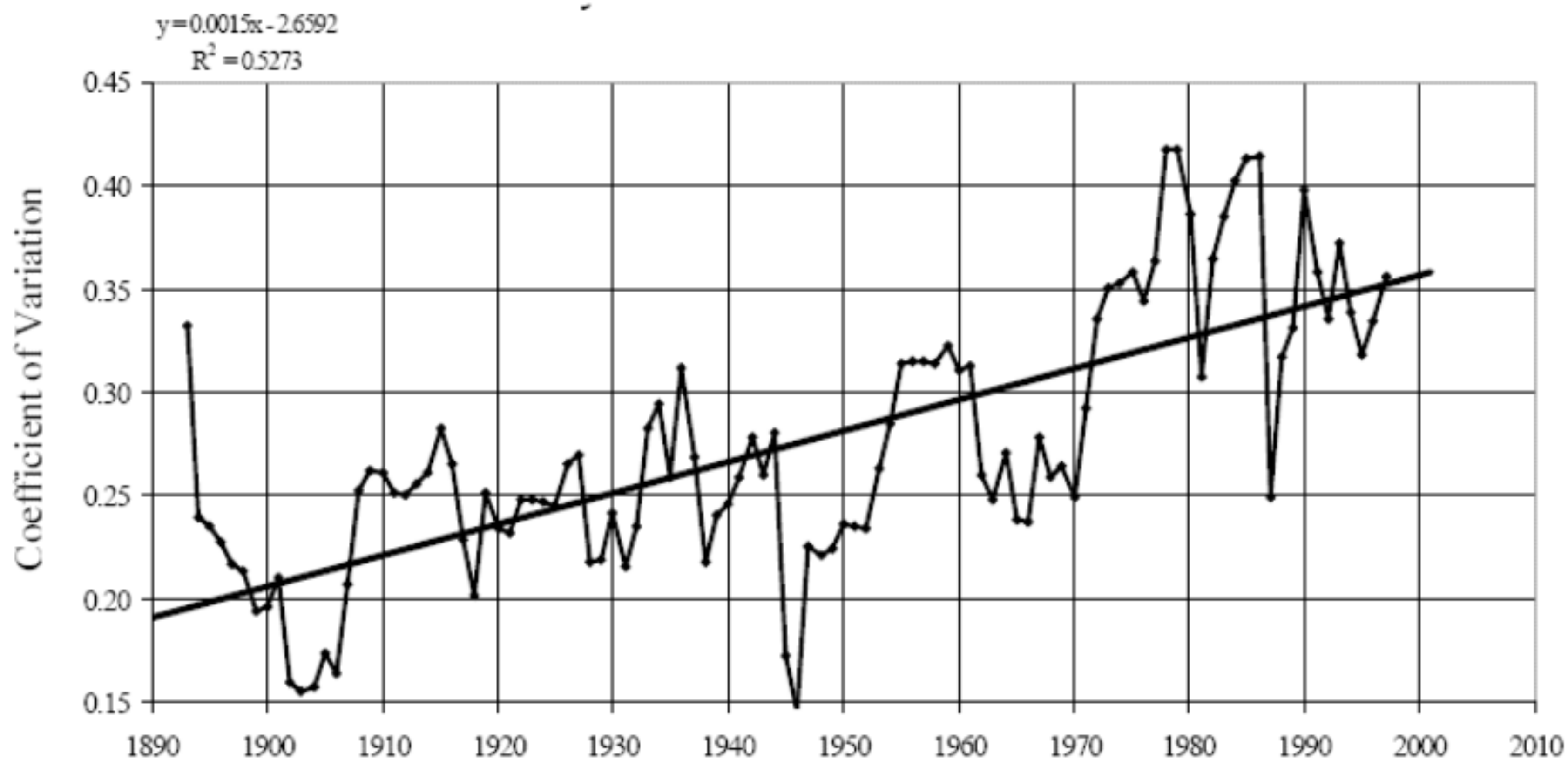


Figure 3.3. *Variation in precipitation over time in California. The solid line is the best-fit regression line. DWR (2006).*

DWR Report 2006

More Variable Precipitation and Runoff

- Large river watersheds influenced by reduced snowpack (less snow melt into rivers) and winter storms with more rain
- Stronger winter inflows and reduced spring inflows in coastal watersheds
- Greater variability in annual precipitation (both drier and wetter years)

Consequences of Changing Runoff

- More variable runoff can influence several important variables:
  - Salinity
  - Nutrients
  - Dissolved oxygen
  - Alkalinity
  - Sediments and contaminants

Sea Level Rise in CA

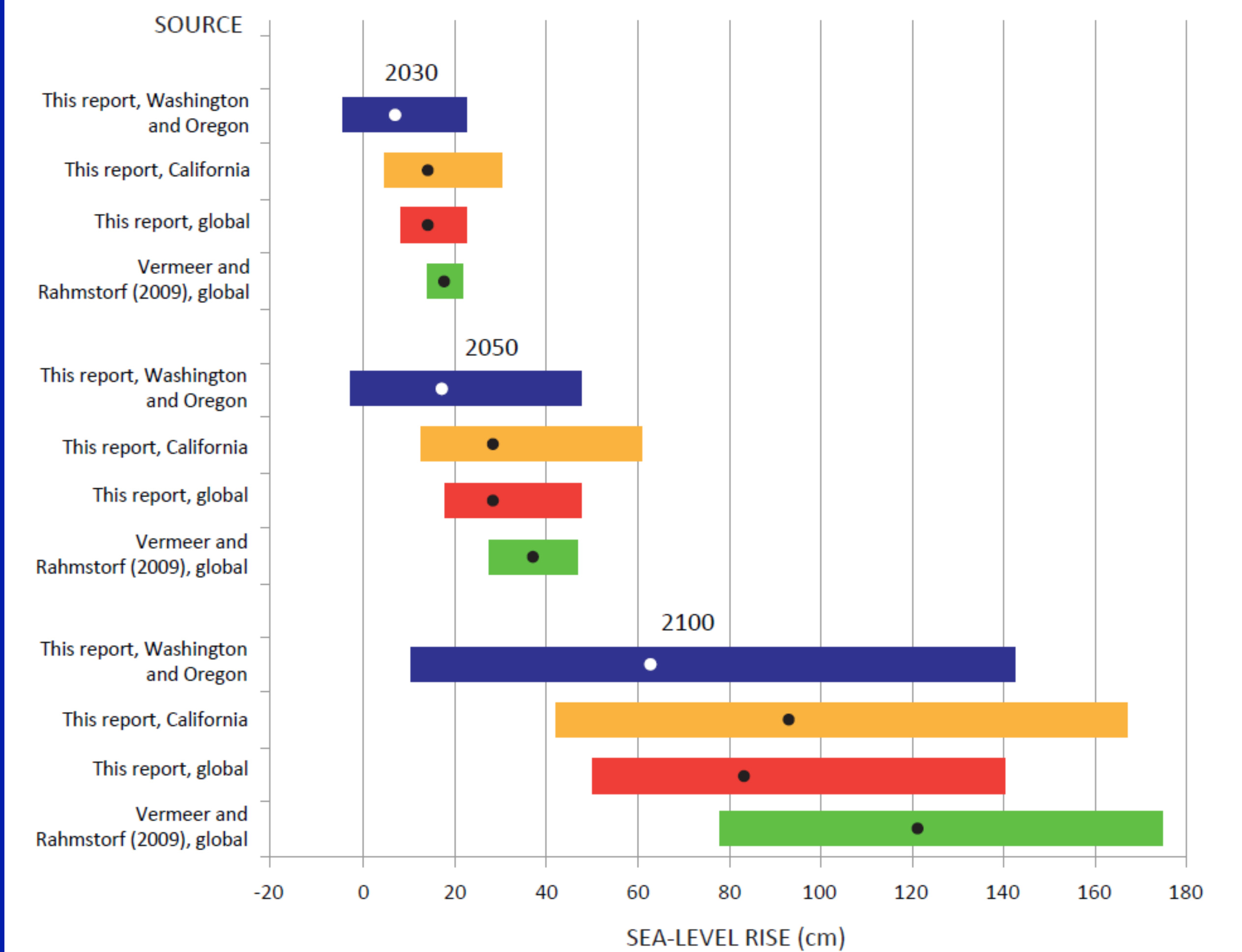


FIGURE 5.10 Committee's projected sea-level rise for California, Oregon, and Washington compared with global projections. The dots are the projected values and the colored bars are the ranges. Washington and Oregon = coastal areas north of Cape Mendocino; California = coastal areas south of Cape Mendocino.

NRC Committee Report 2012

Expected SLR in Central CA

- Dramatic sea level rise (SLR) is expected in central CA where land is subsiding
- Recent estimates for central and southern CA have increased to 75 cm by 2050 and 190 cm by 2100 (NRC Committee 2012)
- SLR can affect ocean and river inputs, timing of tidal cycles, and overall circulation in bays and estuaries

Increasing Ocean Acidification

- Ocean water pH is strongly influenced by atmospheric levels of carbon dioxide
- Increasing atmospheric carbon dioxide results in increased acidity (carbonic acid in water)
- Deeper ocean waters are more acidic than surface waters
- Thus, projected increases in upwelling will contribute to decreases in pH of offshore waters

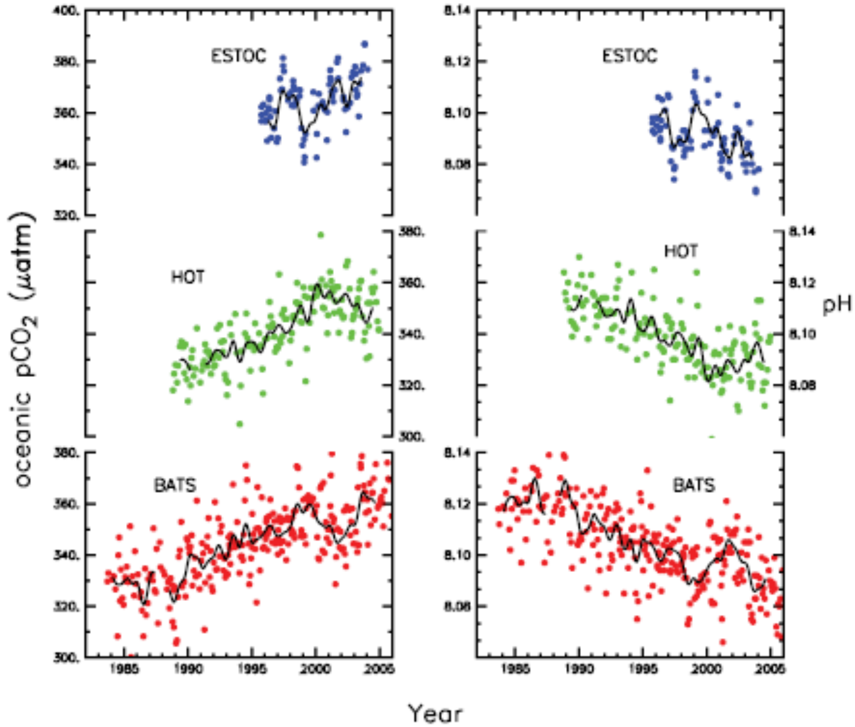
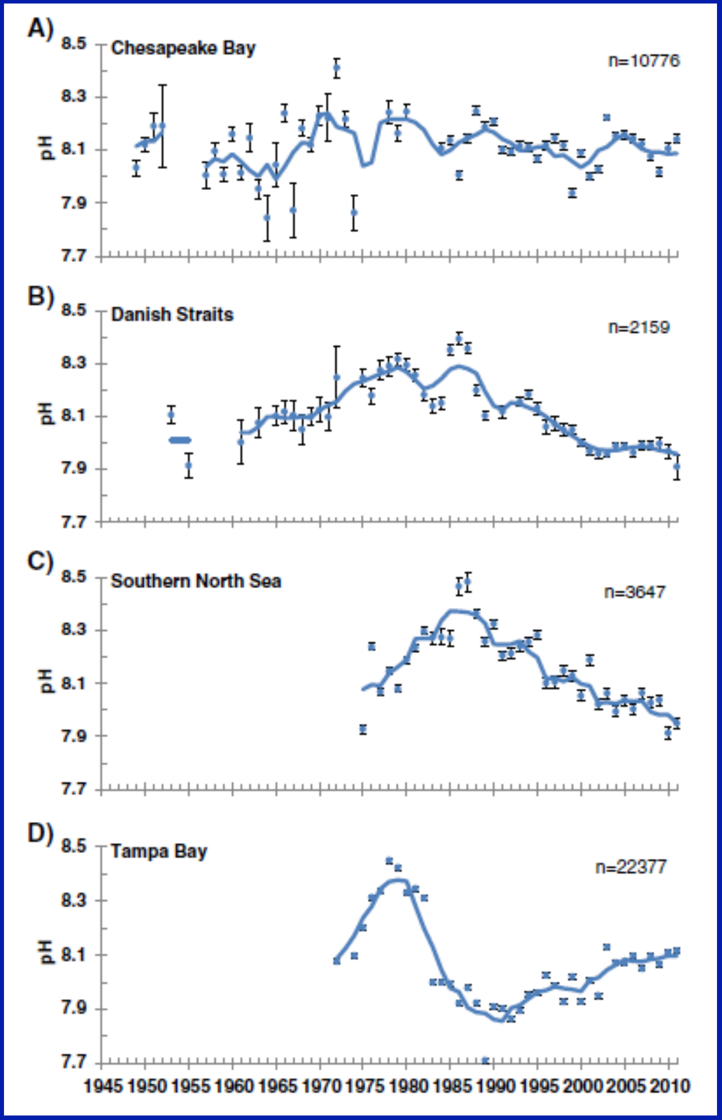


Figure 5.9. *Changes in surface oceanic pCO_2 (left; in μatm) and pH (right) from three time series stations: Blue: European Station for Time-series in the Ocean (ESTOC, 29°N, 15°W; Gonzalez-Dávila et al., 2003); green: Hawaii Ocean Time-Series (HOT, 23°N, 158°W; Dore et al., 2003); red: Bermuda Atlantic Time-series Study (BATS, 31/32°N, 64°W; Bates et al., 2002; Gruber et al., 2002). Values of pCO_2 and pH were calculated from DIC and alkalinity at HOT and BATS; pH was directly measured at ESTOC and pCO_2 was calculated from pH and alkalinity. The mean seasonal cycle was removed from all data. The thick black line is smoothed and does not contain variability less than 0.5 years period.*

IPPC 4th Assessment Report 2007

Estuarine Acidification?

- Projected pH changes in bays and estuaries more complicated
- Inputs from watersheds can outweigh atmospheric inputs
- Increases in alkalinity, eutrophication (plant photosynthesis) can increase pH levels
- Future levels difficult to project



Duarte et al. Estuaries & Coasts 2013

Direct Consequences of Climate Change for Oysters

- Increased surface water temperatures may increase growth rates
- Low DO could decrease growth or survival
- Low pH can reduce growth (Hettinger et al. 2012) can ‘potentially’ reduce survival
- Variable precipitation/runoff and salinity could reduce growth/survival
- Rising sea levels could influence ocean inputs and estuarine circulation

Indirect Consequences of Climate Change for Oysters

- Variable runoff/outflow may influence larval dispersal and connectivity
- Increased temps could have several affects
  - Increased overgrowth by algae and space competitors
  - Increased phytoplankton abundance
  - Increased consumption by predators
- Spatial variability means changes in refugia and optimal sites