Transboundary Issues

Introduction

The movement of certain pollutants by natural processes, meteorological forces and human activities can produce environmental threats that extend beyond California's geographical boundaries, in some cases producing global impacts. For example, the worldwide emissions of greenhouse gases into the earth's atmosphere may result in global temperature and climate changes. Emissions of chlorofluorocarbons may result in global stratospheric ozone depletion.

Pollutants that originate in other states, countries or ecosystems, carried by atmospheric air currents, watersheds, trade, and travel can impact California; conversely, the same mechanisms can transport pollutants from California to other jurisdictions. For example, non-native organisms can enter the state's borders with the movement of people and goods. Ballast water in ocean-going vessels has been shown to be a carrier of alien aquatic species. Hazardous wastes are transported to and from California's borders for treatment or disposal. Air emissions from California may move into neighboring states, and vice-versa. Of special interest is the California/Mexico border region, the area within 100 kilometers of either side of the border.

Transboundary Indicators

Global pollution

Climate change

Carbon dioxide emissions (Type I)

Air temperature (Type I)

Annual Sierra Nevada snowmelt runoff (Type I)

Sea level rise in California (Type I)

Stratospheric ozone

Stratospheric ozone depletion (Type I)

Trans-border pollution

California-Baja California, Mexico border issues

Air pollutants at the California/Baja California, Mexico border (Type I)

Domestic border issues

Amount of hazardous waste imported/exported (See Land, Waste and Materials Management Section) (Type II)

International border issues

Ballast water program (Type III)

Issue 1: Global Pollution

Environmental pollution can produce adverse impacts locally (or in proximity to the source of the pollution), regionally, nationally and, in certain cases, globally. Air masses and ocean currents follow circulation patterns that can disperse pollutants and contaminate even the most remote and pristine environments on the planet.

Sub-issue 1: Climate change

The term "climate change" refers to changes in climate over time, with "climate" being defined as the average pattern of weather for a particular region. Elements of the climate include temperature, precipitation, humidity, wind velocity, phenomena such as fog, frost, and hailstorms, and other measures of the weather. Since the earth's climate is never static, however, the term climate change is used to imply a significant change from one climatic condition to another (U.S. EPA, 1999). Such changes can be due to natural processes (such as ice age cycles), or to human activities, such as alteration in the atmospheric concentration of certain gases, commonly referred to as "greenhouse gases" (GHGs).

Indicators

Carbon dioxide emissions (Type I)

Air temperature (Type I)

Annual Sierra Nevada snowmelt runoff (Type I)

Sea level rise in California (Type I)

GHGs, which are emitted from both natural and anthropogenic sources, include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), fluorocarbons and chlorofluorocarbons. These gases play a role in the "greenhouse effect," a natural phenomenon that helps regulate the temperature of the earth. Simply put, the sun heats the earth and some of this heat, rather than escaping back to space, is trapped in the atmosphere by clouds and GHGs. The effect of this is to warm the earth's surface and the lower atmosphere. (U.S. EPA, 1999).

Scientists believe that human activities are increasing the atmospheric concentrations and distributions of GHGs, leading to a phenomenon known as global warming. CO_2 from the combustion of fossil fuels is the largest source of GHG emissions (about 80 percent of United States GHG emissions and about 87 percent of California emissions). The United States emits 25 percent of the world's CO_2, the European Union 16 percent, China 12 percent, and Japan and Australia 8 percent. Examples of other sources of GHGs include CH_4 emissions from landfills and N_2O from agriculture and combustion. Atmospheric concentrations of GHGs have sharply increased since the Industrial Revolution.

The National Research Council (NRC, 2001a) climate change analysis requested by President George W. Bush and the Third Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) conclude that the global climate is changing at a rate unmatched in the past one thousand years. The IPCC assessment cites new and stronger evidence that most of the global warming observed over the last fifty years is attributable to human activities and that anthropogenic climate change will persist for many centuries. However, while the NRC report generally agrees with the IPCC's Third Assessment, it does not rule out that some significant part of these changes is also a reflection of natural variability. The observed changes over the last fifty years and those projected for the future include sea level rise, higher maximum air temperatures, more hot days, fewer cold days, and greater extremes of drying and heavy rainfall. A more recent report from the NRC cites that in the earth's past, there were episodes of abrupt climate changes during periods of gradual temperature changes. GHG warming and other human alterations of the earth's system may increase the possibility of large, abrupt, and unwelcome regional or global climatic events (NRC, 2001b).

Climate changes can have profound impacts on human health directly through higher temperatures and increased frequency of heat waves, or indirectly, by increasing concentrations of ground-level ozone (O_3) or increasing the risk of some infectious diseases. Rapid changes in climate can disrupt ecosystems and negatively impact many species by, among other things, altering water and food availability. Further, agriculture, forestry, fisheries and water resources can be adversely impacted, resulting in severe economic consequences.

The 1992 United Nations Framework Convention on Climate Change aimed to stabilize atmospheric GHGs concentrations at a level that would prevent dangerous interference with the climate system. As part of the Convention, national inventories of anthropogenic GHG emissions are to be published and periodically updated. In 1997, the Kyoto Protocol was adopted to move the international community closer to achieving the Convention's objective. The parties to the Kyoto Protocol have agreed to legally binding commitments to reduce the collective emissions of six types of GHGs by at least 5.2 percent of the 1990 levels by 2012. In order for the Kyoto Protocol to take effect, it must be ratified by 55 percent of the countries representing at least 55 percent of the global CO_2 output from industrial countries. As of September 2001, 39 developing nations have ratified the Kyoto Protocol, including one industrialized nation, Romania. The United States and the major European nations have not ratified the Protocol.

The State of California continues to be a leader in efforts to address global climate change, with legislation and programs in place to improve energy efficiency, promote renewable energy sources, and lower emissions from the transportation sector. Senate Bill 1771 (enacted as Chapter 1018, Statutes of 2000) mandated the creation of a voluntary GHG registry aimed at recognizing California companies and organizations that make efforts to record and reduce their GHG emissions. The California Climate Action Registry has offices in Los Angeles and is developing a website at www.climateregistry.org. A Joint Agency Climate Team, consisting of the California Resources Agency, Cal/EPA and other state agencies, has been established to coordinate and integrate program activities related to climate change. Such activities include climate policy, research and technology development, and public information dissemination. The Climate Change Program of the California Energy Commission (CEC) is responsible for developing policies and programs to reduce GHG emissions statewide. In addition, the CEC's Public Interest Energy Research (PIER) Program currently funds research on the potential impacts of climate change in California.

Environmental indicators have been selected to help track certain parameters of climate change and GHG as they relate to California.

Indicator

Stratospheric ozone depletion (Type I)

Sub-issue 2: Stratospheric ozone

Stratospheric ozone formed in the upper atmosphere 6 to 39 miles high protects the earth's surface from much of the harmful ultraviolet (UV) light rays that are emitted by the sun. Until the late 1990s, increasing levels of chlorine and bromine in the stratosphere, originating primarily from chlorofluorocarbon emissions at ground level, have resulted in degradation of stratospheric ozone. Lower levels of stratospheric ozone may lead to higher amounts of UV radiation reaching the earth's surface. Exposure to excessive UV radiation has been linked to increased incidence of skin cancer and eye cataracts, damage to crops and aquatic organisms, and deterioration of synthetic materials. Over North America, including California, cumulative losses of about 10 percent in the winter/spring and a 5 percent loss in the summer/autumn, have occurred since the mid-1960s. Additional atmospheric processes over the Polar Regions cause seasonally greater depletion of stratospheric ozone, such that a recurring ozone "hole" often forms over Antarctica.

The 1987 Montreal Protocol established timetables for phasing out ozone-depleting substances. Peak values of ozone-depleting substances in the lower stratosphere appear to have been reached around 1997-98; however, they have remained at high levels, and ozone depletion is continuing as a result of past emissions. Hydrochlorofluorocarbons (HCFCs), which have largely replaced CFCs, generally have less than 5 percent of the ozone-depleting potential of CFCs. HCFCs have many of the same uses as CFCs and are increasingly employed as interim substitutes for CFCs. Due to their ozone-depleting and global warming potential, the production of these compounds will likely be phased out by the year 2030.

Ozone depletion over California has been monitored from a site near Fresno since 1983. Other longer running monitoring sites at similar latitudes in the continental United States have documented losses for over 20 years. However, the lack of long-term monitoring of surface UV levels along with other uncertainties cannot, as yet, determine if ozone depletion over California will result in an increased UV exposure to the public.

Issue 2: Trans-Border Pollution

The regulation of sources of pollution is traditionally undertaken to protect the citizens of a political jurisdiction from the deleterious effects of exposure to a hazardous substance. Pollution does not necessarily cease to become a threat to human health and the environment when crossing from the jurisdiction of one country into another.

Sub-issue 2.1: California/Baja California, Mexico border issues

California and Baja California, Mexico have cultures, legal structures, and social and economic interactions that create a unique set of environmental issues in this region. The border region is defined as the area within 100 kilometers of either side of the border. The Border Environmental Program (BEP) was established to address common concerns along the border. The Program consists of a multi-disciplinary group of professionals representing the states of California and Baja California. California is represented by Cal/EPA, the Resources Agency, the Department of Health Services, the Trade and Commerce Agency, the Department of Justice, and the Governor's Office of Emergency Services. Baja California is represented by the Ecology Directorate, the State Public Services Commissions, the Federal Attorney General's Officer for Environmental Protection (PROFEPA), and the Secretariat of the Environment and Natural Resources (SEMARNAT). The Border Affairs Unit within Cal/EPA directs the BEP; 22 Border Coordinators throughout Cal/EPA work with their individual departments and Mexican counterparts.

Hazardous waste

Under the North American Free Trade Agreement (NAFTA), United States (U.S.) companies that build maquiladoras, assembly plants in Mexico that import raw material and export finished goods to other countries, must ship hazardous waste produced at these facilities back to the United States. Some wastes do come back as properly documented hazardous waste (i.e., with a hazardous waste manifest), while other wastes are relabeled as product and sent to recycling firms in California.

On-site dumping of waste is occurring at Mexican maquiladoras, creating potentially hazardous working conditions and public health threats to nearby communities. In addition, an increasing number of abandoned waste sites are being identified in close proximity to communities.

Pesticides

U.S. Environmental Protection Agency- and California-registered pesticides purchased in the U.S. may legally be used in Mexico on commodities for which use is not legal in this country. Consequently, fresh produce from that nation may have illegal pesticide residues. Although still low, the violative rate of illegal residues on Mexican imported produce is twice the rate for domestic produce. Moreover, the protective measures mandated on the U.S. authorized product label may not always be followed in another nation, creating a potential for environmental contamination and worker exposure. Mexican agricultural workers in the U.S. made ill by pesticide exposure may be more likely to seek medical care in Mexico. In addition, highly toxic pesticide products produced in Mexico are illegally imported into the U.S. and used in residential settings for pest control, with associated problems of illness and environmental contamination.

Water pollution

The New and Tijuana Rivers flow from Baja California across the Southern California border. Both rivers are considered impaired water bodies, under California and federal laws, due to serious chemical and pathogenic contamination. Wastewater is not fully treated in most border cities. Severe water shortages are projected in border communities due to water pollution, industrial demand, and population growth. Increased salinization and the nutrient loading of the Salton Sea, partly as a result of inflow from the New River, are causing fish kills that can adversely affect migratory birds.

Indicator

Air pollutants at the California/ Baja California, Mexico border (Type I)

Air pollution

Air pollutants from mobile and stationary sources and from agriculture are transported both north and south across the border. Most cars in Baja California are older and lack emission controls. Traffic congestion at border crossings may significantly contribute to air pollution on both sides of the border. Unpaved roads and agricultural practices, such as burning and plowing, contribute to high particulate levels.

Sub-issue 2.2: Domestic border issues

California shares air basins and watersheds with three other U.S. states — Oregon, Nevada, and Arizona. Air pollution generated by industrial facilities and vehicular traffic in California can be carried by winds and primarily affect air quality of these neighboring states. Water quality concerns also exist; for example, issues relating to the Lake Tahoe watershed are shared by both Nevada and California.

The interstate movement of goods can lead to the introduction of plants and animals that are not indigenous to California. For example, fruit orchard infestations of the red imported fire ants in the agricultural regions of California's San Joaquin Valley have been traced back to colonies that hitchhiked on beehives shipped to California from Texas; the star thistle weed probably arrived in alfalfa shipments, and the mediterranean fruit fly (native to the Hawaiian Islands and various parts of the world) and glassy-winged sharpshooter fly (native to the southeastern U.S. and northeastern Mexico) in nursery stock and ornamental plants. California has suffered significant ecological and economic losses as a result of these and other non-indigenous species.

Another domestic border issue is the export and import of hazardous waste to and from other states in the U.S.

Sub-issue 2.3: International border issues

Pollutants in one ecosystem can often be traced to sources of pollution hundreds or thousands of miles away. International border issues may arise from the import and export of produce as well as legal and illegal products and wastes. The shipment of hazardous wastes from California to other countries raises public health and environmental equity concerns.

In addition to chemical pollutants, plants and animals that are not indigenous to California have been introduced into the state. These can compete with, and even eliminate indigenous species, leading to devastating consequences, such as the disruption of aquatic ecosystems by non-indigenous species carried in ballast waters in international ocean-going vessels.

Indicator

Amount of hazardous waste imported/exported (see Land, Waste and Materials Management Section)

Indicator

Ballast water program (Type III)

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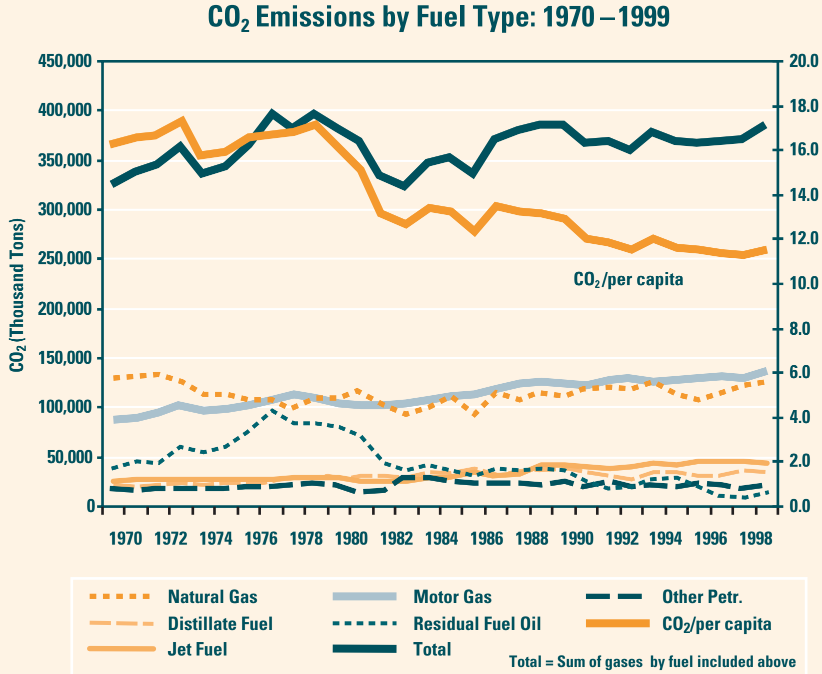
Type I

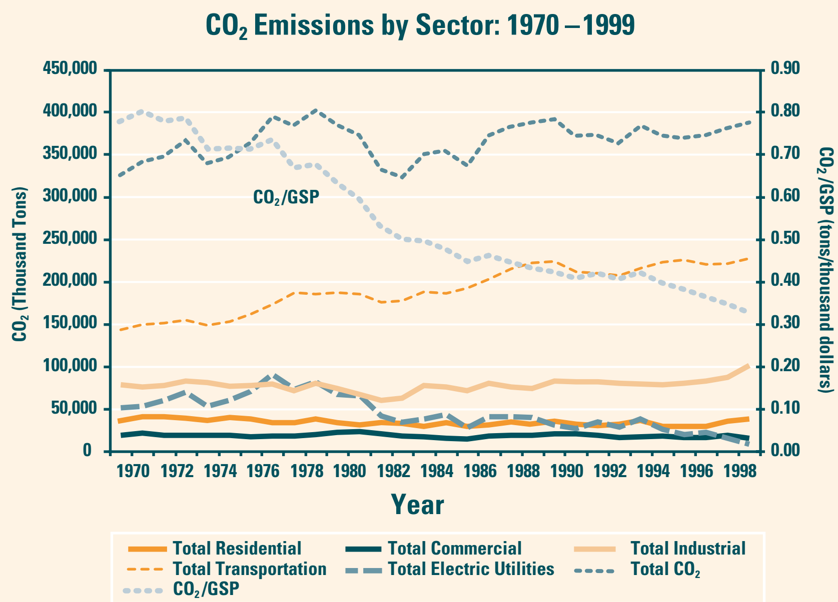
Level 3
Goal 4

Carbon Dioxide Emissions

Emissions have increased slightly since the 1970s.



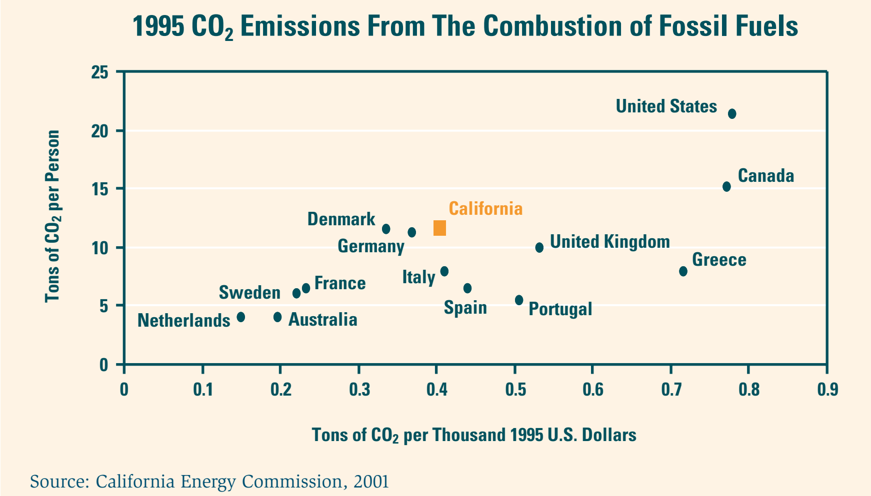
Source: California Energy Commission, 2001



Source: California Energy Commission, 2001

What is the indicator showing?

California emissions of carbon dioxide (CO_2) from the burning of fossil fuels have increased slightly from 1970 to 1999. However, emissions on both a per capita and per $1,000 gross state product (GSP) basis have been decreasing, with the latter at a more rapid rate (Franco, 2001).



What is the indicator showing?

For both CO_2 emissions per capita and per $1,000 of the economy, the California average is lower than the average for the rest of the United States and Canada. The state's economy produces CO_2 at a lower rate than five other developed countries (see graph) (CEC, 2001).

Why is this indicator important?

CO_2 emissions from the combustion of fossil fuels account for the largest proportion of greenhouse gas emissions (GHG). The California Energy Commission (CEC) estimates that CO_2 represents approximately 87 percent of the "global warming potential" (GWP) of California's GHG emissions. The GWP is an index used to translate the level of emissions of various GHGs into a common measure based on their potential to cause global warming, usually compared to CO_2.

GHGs in the atmosphere retain heat that is radiated by the earth's surface back into space. These gases include both natural gases emitted from natural and anthropogenic sources, such as CO_2, methane (CH_4), and nitrous oxide (N_2O), and synthetic chemicals, such as hydrofluorocarbons (HFC). Atmospheric concentrations of GHGs have increased since the Industrial Revolution, enhancing the heat-trapping capability of the earth's atmosphere. Tracking trends in CO_2 emissions from fossil fuel combustion will allow an assessment of the state's contributions to global GHG emissions.

What factors influence this indicator?

Levels of CO_2 emissions are based upon patterns of fossil fuel consumption, which in turn are influenced by a number of factors, including population growth, motor vehicle miles traveled, economic conditions, energy prices, technological changes resulting in improved energy efficiency, the availability of non-fossil alternatives, consumer behavior, and weather. For example, improved economic conditions can result in an increased number of motor vehicles and increased motor vehicle miles traveled. Most of the emissions of CO_2 in California are generated from motor vehicle use and electrical power generation. Coal use in California accounts for only two percent of the total emissions from fuel combustion (CEC, 1998), although California imports electricity from other states that do use coal. (Coal generates more CO_2

emissions than other fuels used to produce electrical power.) Emissions from electricity generated out of state are not in the California emissions inventory because national and international convention requires the CEC to include only in-state fuel consumption in the emissions inventory. If this power were generated in California by power plants in compliance with state laws and regulations, these in-state emissions would have increased in the 1990s by about 5 to 11 percent. Due to its relatively mild weather, California's heating-related fuel consumption tends to be lower than many other states'.

The adoption and implementation of policies at the state, national and international levels can have a significant impact upon CO_2 emissions. The objective of the 1992 United Nations Framework Convention on Climate Change was to achieve stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Parties to the convention agreed to prepare inventories of GHG emissions that originate from human activities and removals of CO_2 by carbon sinks. The 1997 Kyoto Protocol set legally binding targets for the reduction of six GHGs by at least five percent of 1990 levels by 2012.

The indicator illustrates that total emissions in California have not gone up significantly since the 1970s. This is, in part, due to the shift from residual fuel oil to natural gas in California's power plants. Residual fuel oil emits more carbon dioxide per unit of heat released during combustion than natural gas. The shift to natural gas was the result of lower natural gas prices in the past and stringent air quality regulatory requirements. Other state policies such as energy conservation programs have also contributed to the pattern of emissions. One other reason CO_2 emissions have remained relatively stable over the past 30 years may be attributed to the higher fuel economy of newer motor vehicles and the retirement of older, less fuel efficient motor vehicles.

In the past, California has imported about 33 percent of its electricity from other states. To meet the state's electricity demand, more power plants are being constructed. Fossil fuel consumption from these new power plants may increase the in-state CO_2 emissions. However, this will be tempered by the fact that the new power units will be much more efficient than many current power plants in operation and therefore produce much less CO_2 emissions per unit of electricity generated.

The decline in CO_2 emissions per $1,000 GSP is an indication of the increased energy efficiency of the economy, a higher reliance on fuels with lower carbon content, and a structural shift to a service-oriented economy. Increases in CO_2 emissions in the transportation sector are driven, in part, by the increase in motor gasoline consumption due to increased vehicle miles traveled, and the increased use of jet fuel due to increased air transportation (CEC, 1998).

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Technical Considerations:

Data Characteristics

The indicator is based upon fossil fuel use data in California starting in 1970. The next update to the statewide GHG Emissions Inventory from the CEC will be released by January 2002. As was done for the previous inventory (CEC, 1998), the update will include CH_4 and N_2O emissions and, for the first time, address all of the other gases covered by the Kyoto protocol. For the non-CO_2 gases, the inventory will cover the period starting in 1990 to the most recent year with complete energy and non-energy data necessary to estimate emissions. For easy comparison, all the emissions will be reported as CO_2 equivalents using their respective Global Warming Potentials (GWP).

Strengths and Limitations of the Data

The indicator accounts for only one GHG, and is based upon fossil fuels only. Emissions of other GHGs and CO_2 emissions from sources other than fossil fuels would provide a more complete picture of California's total emissions of GHGs. However, since CO_2 from fossil fuel combustion makes up almost 90 percent of the GWP of all GHG emissions (IPCC, 2001), the indicator is a reasonable approximation of California's contributions to global concentrations of GHGs. As more information becomes available for emissions of GHGs other than CO_2, or non-fossil fuel sources of CO_2, consideration will be given to expansion of the CO_2 indicators for climate change.

CH_4 is the main constituent of natural gas and has a GWP 21 times that of CO_2. CH_4 is also formed as a result of solid waste landfill decomposition of organic matter in an anaerobic environment, and from livestock digestive processes and manure management. N_2O emissions from fertilizer use in agricultural soil management are based on data from the Department of Food and Agriculture's Materials Tonnage Report (CEC, 1998). N_2O has a GWP 310 times that of CO_2.

National and state-level inventories should not count emissions due to the consumption of fuels used for international transport. The amount of fuel purchased in California and used for international transport is expected to be significant due to its geographical location. However, the task of subtracting these fuels from the state consumption statistics is extremely difficult. For this reason, the data presented in the above figures include fuels purchased in California and used for international transport. Future updates to the state-level inventory prepared by the CEC will try to estimate the consumption of these fuels since 1990, which is considered as a baseline year in most GHG policy initiatives.

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Type I

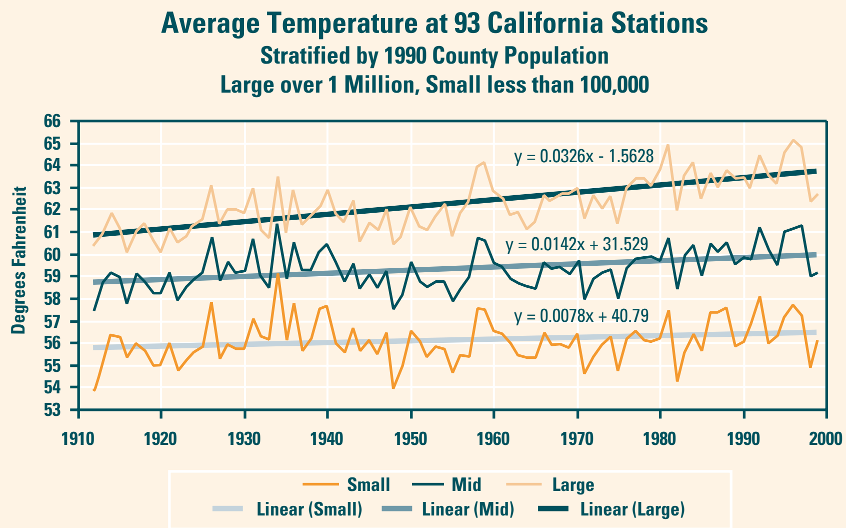
Level 4
Goal 4

What is the indicator showing?

Air temperature has increased over the past 90 years, more so in large cities than in rural areas. Large urban areas are generally warmer than rural areas, and can have temperatures up to 5 degrees Fahrenheit (°F) higher, creating their own weather belt. This can be due to the removal of vegetation and trees, the presence of buildings and streets (which reflect heat stored in pavement), and the production of heat by human activities. The indicator illustrates trends of average yearly temperatures for three groups of counties. Counties with the largest populations (over one million residents) had the highest temperature increase. Conversely, counties with less than 100,000 people had the lowest average rate of temperature increase. These tend to be rural areas and are more likely to be representative of global influences, natural and man-made. The temperature increase rate of 0.7° F (0.5° C) per century from the rural group agrees with a global estimated mean surface temperature increase of 0.5 to 1.0° F (0.3 to 0.6° C) since the 19th century.

Air Temperature

Air temperatures have increased 0.7 to 3.0° F in the past century.



Source: James Goodridge, 2001

Why is the indicator important?

Average global earth surface temperatures have indicated an increase of 0.5° to 1.0°F since the late 19th century. The 20th century's ten warmest years all occurred in the last 15 years of the century. Seventeen of the eighteen warmest years in the 20th century occurred since 1980. In 1998, the global temperature set a new record, exceeding that of the previous record year, 1997 (National Assessment Synthesis Team, 2000). The graph presented here reflects California's temperature trend.

The indicator will track trends in statewide surface air temperatures and regional variations, allowing for a comparison of temperature changes in California with those occurring globally. Temperature data have been collected at many weather stations in the state for almost a century.

What factors influence this indicator?

According to the United Nation's Intergovernmental Panel on Climate Change (IPCC, 2001), human activities, including the combustion of fossil fuels such as coal and oil, land use changes and agriculture, are increasing the atmospheric concentrations of greenhouse gases (GHGs). Other than water aerosols, carbon dioxide (CO_2) is the most predominant GHG. Other GHGs are methane and nitrous oxide. These GHGs retain heat that would have been radiated from the earth back into space. Increases in the concentrations of GHGs are predicted to change regional and global climate and climate-related parameters such as temperature, precipitation, soil moisture, and sea level (NARIP, 1997).

Local geographical features affect temperatures in the many diverse areas that make up California. In fact, on any given summer day, California may experience both the hottest and the coldest air temperatures in the continental United States. Ocean currents upwelling and sea surface temperatures along the coast of California influence air temperatures; seasonal variations also occur (Union of Concerned Scientists, 1999). Changes in temperature and flow patterns in the Northern Pacific (Hare, 2000) and in the Eastern tropical Pacific (El Nino Southern Oscillation) cause variations in storm tracks affecting California. The mountains are also a strong influence and sometimes create their own weather. It is possible that changing vegetation cover and the evaporative cooling effects of irrigated crops in the Central Valley may influence summer temperatures to a slight degree.

Research is underway to integrate recorded temperature data from the past century and millennia with other climate-related data. Some research examples include tree ring analyses, fossil sediment records, CO_2 uptake by plants, snowmelt runoff, sea level rise, sea waves, precipitation amounts, storm and drought events, soil moisture, and various cycles of solar activity.

Evidence suggests that global warming rates as large as 3.6° F (2°C) per millennium may have occurred during the retreat of the glaciers following the most recent ice age about 20,000 years ago (National Research Council, 2001; U.S. EPA).

Technical Considerations:

Data Characteristics

California temperature data from the Western Regional Climate Center located in Reno, Nevada were collated and studied by James Goodridge. Average yearly temperature data from 93 recording stations located throughout California were stratified by county population size into three groups: sites in counties with a population of over one million persons; sites in counties with a population of less than 100,000; and sites in counties with populations that fall in between.

Strengths and Limitations of the Data

The location of the temperature recording stations may not have remained consistent over the years. The rural stations tend to be biased toward interior (eastern) counties of California, while most of the other sites are found along the coastal zone, so some of the contrast seen in temperature trends may be from geographic differences, rather than urban effects. In addition, the landscape surrounding the station may have changed with urbanization, and

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heated buildings or devices may have impacted the thermometer readings. Temperatures at airport weather stations may be influenced by radiant heat from the runways. Future data sets for this indicator may be refined to reflect a subset of select temperature monitoring sites that have been screened to have few confounding factors. Although new instruments have been developed, they were not calibrated with the equipment they have replaced. Fortunately, thermometers that have been used over the decades are deemed to be as reliable as current instruments. Historically, volunteers staff weather stations throughout the state. The volunteers select the time of day they wish to consistently record the maximum and minimum temperatures.

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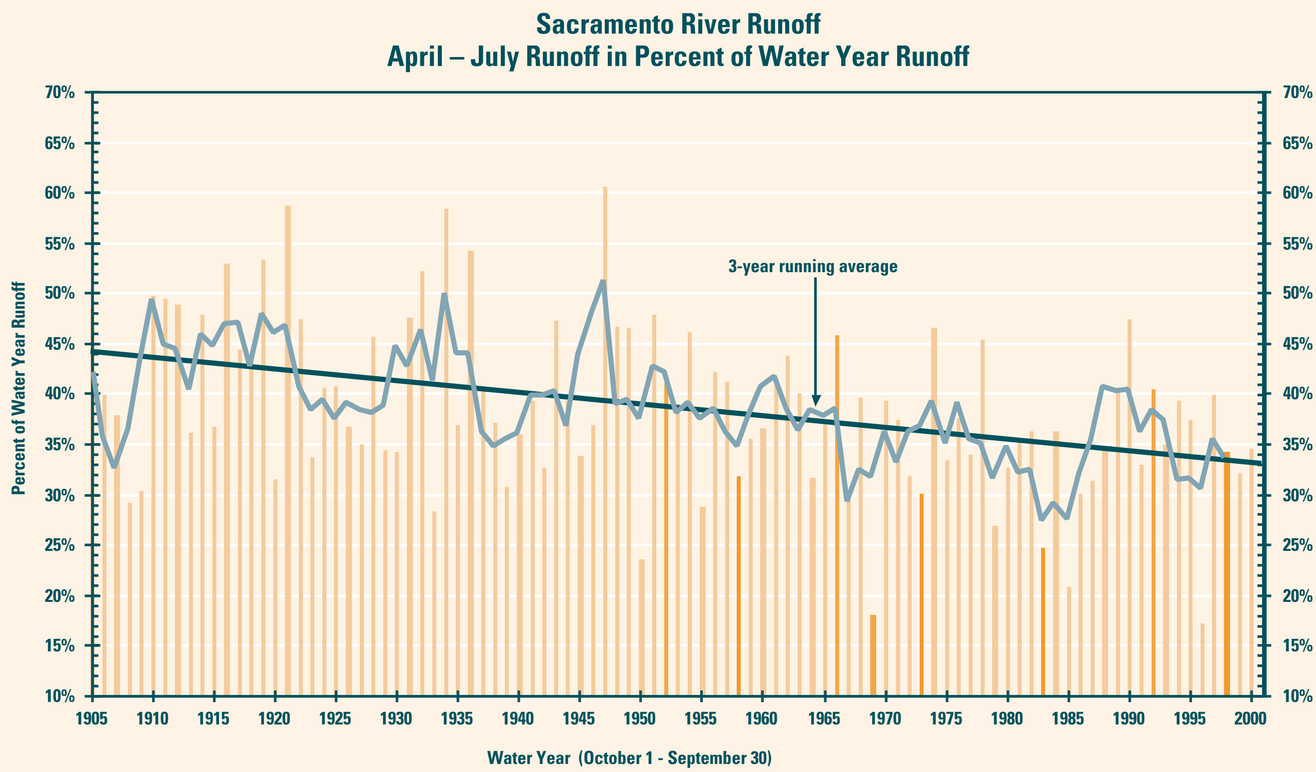
Annual Sierra Nevada Snowmelt Runoff

Spring runoff in California has declined over the past 95 years.

Type I

Level 3
Goal 4



Source: Department of Water Resources

Why is this indicator important?

The fraction of the annual stream discharge that occurs from spring and early summer snowmelt, computed as the ratio of April through July discharge to each water year's (October through September) annual total, provides a measure of temperature-related runoff patterns. Large accumulations of snow occur in the Sierra Nevada and southern Cascade Mountains from October to March. Each winter, at the high elevations, snow accumulates into a deep pack, preserving much of California's water supply in cold storage. Spring warming causes snowmelt runoff, mostly during April through July. If the winter temperatures are warm, more of the precipitation falls as rain instead of snow, and water directly flows from watersheds before the spring snowmelt. Other factors being equal, there is less buildup of snow pack; as a result, the volume of water from the spring runoff is diminished. Lower water volumes of the spring snowmelt runoff may indicate warmer winter temperatures or unusually warm springtime temperatures.

What is the indicator showing?

The percentage of annual runoff fraction during the spring snowmelt period of the Sacramento River has decreased by 12 percent since 1906.

A heavier rainfall burden rather than snow in the winter results in higher flood risks and reduced snow-related recreational opportunities in the mountains. Less spring runoff can reduce the amount of potential summer water available for the state's water needs and hydroelectric power production. Lower runoff volumes can also impact recreation opportunities, and impair cold water habitat for salmonid fishes (Maury Roos, 2000).

What factors influence this indicator?

The warming of global climate might increase evaporation rates, thereby potentially increasing precipitation and storms in the state. The yearly ratio of rain to snow depends on temperature, as does snow level elevations. The warmer the storm temperature, the higher the elevation at which snow falls and accumulates. Higher elevations of the snow line mean reduced snow pack and lower spring water yields.

Snowmelt and runoff volume data can be used to document changes in runoff patterns. These changes are likely due to increased air temperatures and climate changes. Other factors, such as the Northern Pacific Ocean oscillations and, possibly air pollution, probably contribute to the patterns observed.

During the 20th century, the fraction of annual unimpaired runoff that occurs from April to July, represented as a percentage of total water year runoff from the accumulated winter precipitation in the Sierra Nevada, has been decreasing. "Unimpaired" runoff refers to the amounts of water produced in a stream unaltered by upstream diversions, storage, or by export or import of water to or from other basins. This decreased runoff was especially evident after mid-century, when the water runoff has declined by about ten percent. Most of the change took place after 1950 and the recent two decades seem to indicate a flattening of the percentage decrease.

Technical Considerations:

Data Characteristics

The California Cooperative Snow Surveys Program of the California Department of Water Resources (DWR) collects the data. Runoff forecasts are made systematically, based on historical regression relationships between the volume of April through July runoff and the measured snow water content, precipitation, and runoff in the preceding months (Maury Roos, "Water Supply Forecasting", DWR, 1992).

Related snow pack information is used to predict how much spring runoff to expect for water supply purposes. Each spring, about 50 agencies, including the United States Geological Survey, pool their efforts in collecting snow data at about 300 snow courses throughout California. A snow course is a transect along which snow depth and water equivalent observations are made, usually at ten points. The snow courses are located throughout the state from the Kings River in the South to Surprise Valley in the North. Courses range in

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elevation from 4,350 feet in the Mokelumne River Basin to 11,450 feet in the San Joaquin River Basin.

Since the relationships of runoff to precipitation, snow, and other hydrologic variables are natural, it is preferable to work with natural or unimpaired runoff. The spring runoff is calculated purely from stream flow. These are the amounts of water produced in a stream unaltered by upstream diversions, storage, or by export or import of water to or from other basins. To get unimpaired runoff, measured flow amounts have to be adjusted to remove the effect of man-made works, such as reservoirs, diversions, or imports (Roos, 1992). The water supply forecasting procedures are based on multiple linear regression equations, which relate snow, precipitation, and previous runoff terms to April-July unimpaired runoff.

Major rivers in the forecasting program include the Sacramento, Feather, Yuba, American, San Joaquin, Merced, Tuolumne, Stanislaus, and Kings on the western slopes of the Sierra, and the Truckee, Walker, Carson and Owens on the eastern slopes. Spring runoff percentages have declined throughout much of the mountain range:

River Runoff	Percent Decline in the 20th Century
Sacramento	12
Truckee	15
San Joaquin	8
Kings	7
East Carson and West Walker	9

Strengths and Limitations of the Data

Data have been collected for almost one century for many monitoring sites. Stream flow data exist for most of the major Sierra Nevada watersheds because of California's dependence on their spring runoff for water resources and the extreme need for flood forecasting. The information represents spring rainfall, snowmelt, calculated depletions, and diversions, in part from other rivers and reservoirs. Raw data are collected through water flow monitoring procedures and used along with many other variables in a model, to calculate the unimpaired runoff of each watershed.

Over the years, instrumentation has changed and generally improved; some monitoring sites moved to different locations. The physical shape of the streambed can affect accuracy of flow measurements at monitoring sites, but most sites are quite stable.

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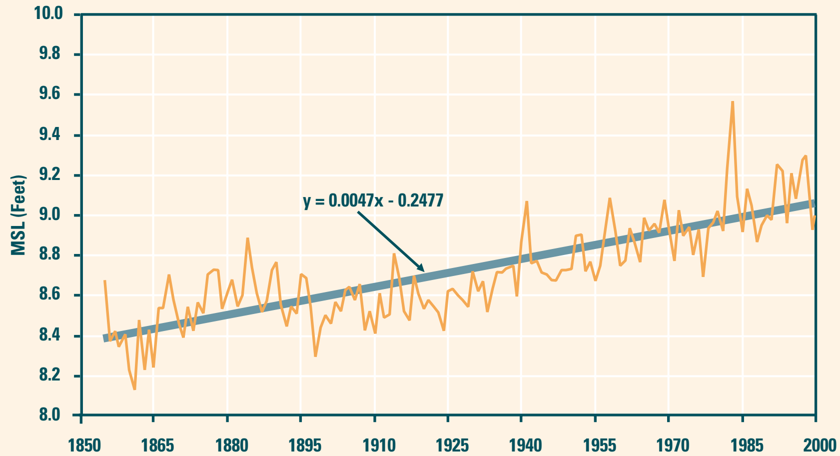
Type I

Level 4
Goal 4

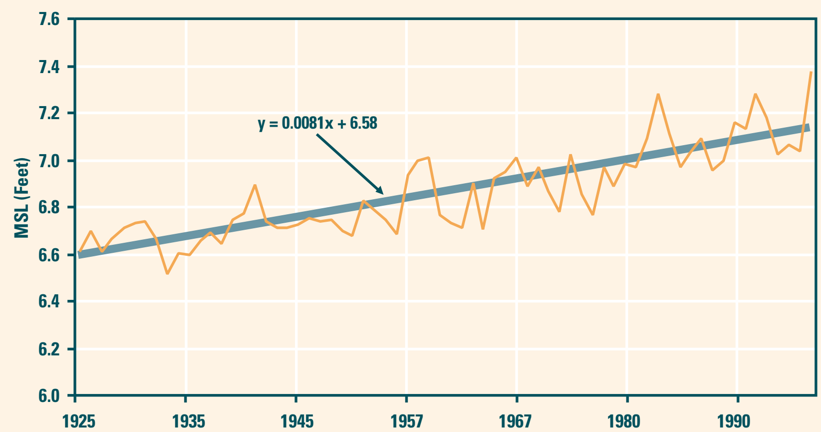
Sea Level Rise in California

Sea levels have increased over the past century.

San Francisco Yearly Mean Sea Level (MSL)
1855-2000



La Jolla Yearly Mean Sea Level (MSL)
1925-1997



Source: National Ocean Service of NOAA

What is the indicator showing?

Sea levels have risen at two tide gauge locations along the California coast.

Why is this indicator important?

Sea level rise provides a physical measure of possible oceanic response to climate change. Average global sea level has risen between four to eight inches during the 20th century, approximately one-tenth of an inch each year. The indicator shows the rising trend in sea level measured at two California stations: San Francisco and in La Jolla. While sea level data from only two California stations are presented, long-term data from 10 of 11 California stations show increases in sea level. Hence, while the rates of increase vary, sea level is increasing almost everywhere in California (Flick, 1999).

The rise in global sea level is attributed to the thermal expansion of ocean water and the melting of mountain glaciers and ice sheets around the globe. At the current rate of melting, the seas could rise another foot over the next 50 years (IPCC, 2001). However, sea level rise is not a new phenomenon, having been a major natural component of coastal change throughout time. The concern is that with possibly increased global warming the rate of change may increase.

Sea level rise and storm surges could lead to flooding of low-lying areas, loss of coastal wetlands such as the San Francisco Bay Delta, erosion of cliffs and beaches, saltwater contamination of groundwater aquifers and drinking water, and impacts on roads, causeways, and bridges. California's hundreds of miles of scenic coastline contain ecologically fragile estuaries, expansive urban centers, and fisheries that could be impacted by future changes in sea level elevation.

What factors influence this indicator?

Along California's coast, sea level already has risen by three to eight inches over the last century (three inches at Los Angeles, five inches at San Francisco, and eight inches at San Diego), and it is likely to rise by another 13 to 19 inches by 2100 (U.S. EPA, 2001). Differences in sea level rise along the coast can occur because of local geological forces, such as land subsidence and plate tectonic activity.

The rise in sea level may be associated with increasing global temperatures. Based on results from modeling, warming of the ocean water will cause a greater volume of sea water because of thermal expansion. This is expected to contribute the largest share of sea level rise, followed by melting of mountain glaciers and ice caps (IPCC, 2001). There has been a widespread retreat of mountain glaciers in non-polar regions during the past 100 years. There is a trend for reduced Arctic sea-ice in the spring (IPCC, 2001).

The earth goes through cycles of warming and cooling, called ice ages, about every 100,000 years. The colder glacial cycles occur when the earth is in an oval elliptical orbit and farther from the sun. Because of the cooling, water from the oceans and precipitation forms ice sheets and glaciers. Much of the water is stored in the polar ice caps and in land bound glaciers. However, during the earth's shorter, circular orbit, it is closer to the sun, warms up, and water flows from melting glaciers to the oceans, driving up sea level. These warming interglacial periods last about 10,000 years. We are about two-thirds of the way through a warming trend now. During the last interglacial period, sea level rose about 20 feet above where it is today (U.S. EPA, 2001). Global warming studies predict that global sea level will rise at an accelerated rate, much beyond that seen in prehistoric "natural" cycles of warming and cooling evidenced by geologic data.

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Technical Considerations:

Data Characteristics

The San Francisco data are obtained from the Golden Gate tide gauge, and the La Jolla data from a gauge at the Scripps Institution of Oceanography pier. The San Francisco record begins in 1855 and represents the longest continuous time series of sea level in North America (Flick, 1998). The record at San Francisco shows a sea level rise of about 8.04 inches from 1855 to 2000, or 5.54 inches per century. This agrees with a much broader collection of tide gauge data that show that global average sea level rose between four to eight inches during the 20th century. The tide gauge record at La Jolla shows an increase in mean sea level of approximately 6.6 inches in the past 75 years, or looking back, perhaps 8.8 inches per century. Tide data from other California monitoring stations are posted at the web site of the National Ocean Service of the National Oceanic and Atmospheric Administration.

Monthly or yearly mean sea level statistics are derived by averaging near-continuous water level measurements from tide gauges. Sea level fluctuates at all time scales, but tide gauges remove the effects of waves and other fluctuations shorter than about 12 minutes. Sea levels change with tides, storms, currents, seasonal patterns of warming, and barometric pressure and wind.

Strengths and Limitations of the Data

Due to astronomical forces, such as the lunar cycle, it is difficult to isolate possible changes due to global warming in the sea level tidal record. Monthly mean sea levels tend to be highest in the fall and lowest in the spring, with differences of about 6 inches. Local warming or cooling resulting from offshore shifts in water masses and changes in wind-driven coastal circulation patterns also seasonally alter the average sea level by 8.4 inches (Flick, 1998). For day-to-day activities, the tidal range and elevations of the high and low tides are often far more important than the elevation of mean sea level. Shoreline damage due to wave energy is a factor of wave height at high tide and has a higher impact on the coast than mean sea level rise.

Geological forces such as subsidence, in which the land falls relative to sea level, and the influence of shifting tectonic plates complicate regional estimates of sea level rise. Much of the California coast is experiencing uplift due to tectonic forces. Mean sea level is measured at tide gauges with respect to a tide gauge benchmark on land, which traditionally was assumed to be stable. This only allows local changes to be observed relative to that benchmark. There are studies in progress that will study the feasibility of monitoring absolute changes in sea level on a global scale through the use of global positioning systems (GPS) satellite altimetry. The GPS may be useful to record vertical land movement at the tide gauge benchmark sites to correct for seismic activity and the earth's crustal movements.

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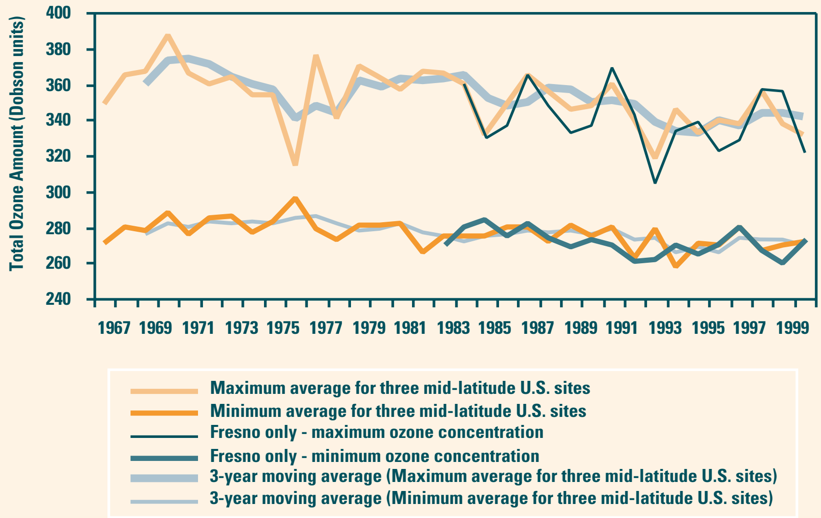
Stratospheric Ozone Depletion

Total stratospheric ozone generally decreased over the mid-latitudes of the Northern Hemisphere (including California and the continental U.S.) from 1979 to the early 1990s, but the downward trend has not continued in recent years.

Maximum and Minimum Stratospheric Ozone Concentrations over Selected U.S. Sites - 1967-2000



Source: Climate Monitoring & Diagnostics Laboratory

Why is this indicator important?

In the upper atmosphere 6 to 30 miles above the earth's surface, stratospheric ozone surrounds the earth and protects it from much of the harmful ultraviolet (UV) light rays that emanate from the sun. Through natural processes involving sunlight and oxygen, ozone is created and destroyed at a rate that produces a relatively stable level of stratospheric ozone. However, the increased presence of chlorine (Cl) and bromine (Br) in the stratosphere, originating primarily from chlorofluorocarbon (CFC) emissions at ground level, has resulted in an increased rate of stratospheric ozone destruction for the past two decades or more.

The degradation of the stratospheric ozone leads to higher levels of UV radiation reaching the Earth's surface. Exposure to excessive UV radiation is known to lead to increased incidences of skin cancers and eye cataracts, damage to crops and aquatic organisms, and deterioration of human-made materials (e.g., certain vinyl or plastic products). The average ozone loss across the globe totaled about 5 percent since the mid-1960s, with cumulative losses of about 10 percent in the winter and spring and a 5 percent loss in the summer and autumn over North America (U.S. EPA, 1996). In terms of how ozone depletion will affect humans, previous work has shown that when total

Type I

Level 4
Goal 4

What is the indicator showing?

Stratospheric ozone monitoring sites located at mid-latitude regions in the Western Hemisphere have noted a gradual decline in stratospheric ozone levels of two to four percent per decade from 1979 to about 1993. The subset of monitoring sites located in the continental United States (in Colorado, Virginia, and Tennessee) and California (established in Fresno in 1983) generally reflects this overall trend. Natural seasonal fluctuations result in maximum and minimum ozone levels each year, reflected above as the months with the average maximum and minimum ozone levels. The three-year moving averages provide an easier means of perceiving trends. Since 1993, the overall rate of decline of stratospheric ozone for the Northern Hemisphere has not continued. While it remains to be seen whether this recent trend continues, it does correlate with the current stabilization of ozone-destroying chlorine and bromine levels in the stratosphere.

ozone decreases, UV increases (U.S. EPA, 1996). The term "total ozone" includes both stratospheric and ground level ozone. A drop of 10 percent in total ozone concentrations increases UV-B radiation on the Earth's surface by some 20 percent (WMO, 1995). Further work has shown that elevated surface UV levels in mid-to-high latitudes were observed in the Northern Hemisphere in 1992 and 1993, corresponding to the low stratospheric ozone levels for those years (U.S. EPA, 1996). However, the lack of long-term monitoring of surface UV levels and uncertainties introduced by clouds and ground-level pollutants, which can greatly affect the amount of UV rays reaching the ground, have not allowed the clear identification of a long-term trend in surface UV radiation.

What factors influence this indicator?

Under natural meteorological conditions, stratospheric ozone concentrations show seasonal variations, as can be inferred from the yearly maximum and minimum ozone levels shown in the graph. The amount of ozone over any one region in California can vary considerably in response to stratospheric winds. Large fluctuations can occur from day to day, and week to week, as well as season to season. However, global stratospheric ozone transport processes normally result in winter-spring maximums and summer-fall minimums over California.

When CFCs and other ozone destroying chemicals (e.g., carbon tetrachloride, methyl chloroform, methyl bromide, etc.) are released into the air, they eventually migrate into the stratosphere where the reaction with UV radiation releases the chlorine (Cl) and bromine (Br) atoms. Cl and Br can then act as catalysts, destroying ozone at a rate greater than it can be created through natural processes. The Cl and Br atoms from CFCs may remain in the stratosphere for decades, destroying many thousands of ozone molecules during their stratospheric life. Exposure to the extreme winter cold in the Polar Regions followed by seasonal warming result in an accelerated destruction of the protective ozone layer during early spring. Thus, stratospheric ozone depletion is greater over the Polar Regions relative to mid-latitude regions of the Northern Hemisphere. Due to colder winters in Antarctica (South Pole) compared to the Arctic region (North Pole), seasonal ozone depletion is greater over Antarctica and has resulted in severe seasonal depletion creating an "ozone hole". The production and use of CFCs, used in refrigeration, air conditioning and other industrial processes, are gradually being phased out under the 1987 Montreal Protocol. Under the Clean Air Act Amendments of 1990, U.S. EPA phased out the production and use of CFCs in the United States completely on January 1, 1996. Production of hydrochlorofluorocarbons (HCFCs) and other compounds with considerably lower or no ozone depleting ability has essentially replaced CFCs. In the United States, production and use rates of HCFCs are increasing (OCED, 1998).

In the lower stratosphere, the amount of Cl and other ozone destroying chemicals reached peak values around 1997-98, but still remain at high levels. Thus far, this trend roughly correlates with the decreased rate of decline of ozone depletion over the mid-latitude regions of the Northern Hemisphere since the early 1990s. Recent studies predict that the current peaking levels of CFC's in the atmosphere should fall to pre-1980 levels by about 2050. However, any changes that occur needs to be examined in the context of changes in amounts of ozone depleting gases in the atmosphere and varying meteorological conditions. Continued monitoring and measurements are essential towards this end.

Technical considerations

Data Characteristics

Yearly maximum and minimum stratospheric ozone levels provide a simple method for showing the long-term trend in stratospheric ozone concentration, which has a natural fluctuation pattern from season-to-season.

The National Oceanic and Atmospheric Administration (NOAA) operates a 16-station global Dobson spectrophotometer network for total ozone trend studies. Four of these stations are located at mid-latitudes in the continental U.S. Weather conditions permitting, daily ozone measurements are collected. Each point on the graph represents either the highest average ozone level recorded for one month (usually in Spring), or the lowest average ozone level recorded in one month (usually in Fall).

Total ozone amounts are measured in Dobson Units. A positive correlation exists between the number of Dobson Units and the absorbance of UV radiation – the greater the number of Dobson Units, the greater the absorption of UV radiation. The definition of a Dobson Unit can be described like so: if all the ozone in a column of air over California were to be compressed to standard temperature and pressure (STP) (0 deg C and 1 atmosphere pressure) and spread out evenly over the area, it would form a slab approximately 3 mm thick. One Dobson Unit (DU) is defined to be 0.01 mm thickness at STP. Thus, the ozone layer over California is 300 DU.

Strengths and Limitations of the Data

Collection of ozone data from the Fresno station began in 1983. To better illustrate the ozone trend, averaged data from three other mid-latitude stations are shown going back to 1967. However, all four stations presented similar trends and concentrations in ozone levels and are representative of mid-latitude regions of the Northern Hemisphere, which includes California and much of the continental United States.

Factors in addition to the level of Cl and Br in the stratosphere may have an influence on stratospheric ozone levels. For example, unusually cold polar winters are known to greatly accelerate ozone destruction in the Polar Regions, and thus may subsequently affect mid-latitude ozone levels through mixing by stratospheric winds. Also, the volcanic eruption of Mt. Pinatubo appeared to cause a worldwide downward trend of total ozone during 1991-1992.

Consistent collection of ground level UV radiation data to corroborate ozone depletion findings has not been performed. Thus, the UV radiation exposure risk resulting from depletion of total ozone is unknown.

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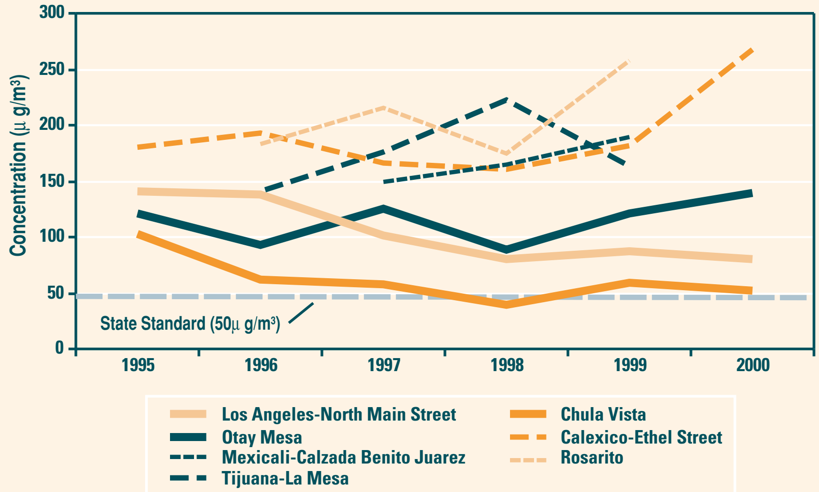
Air Pollutants At The California/Baja California, Mexico Border

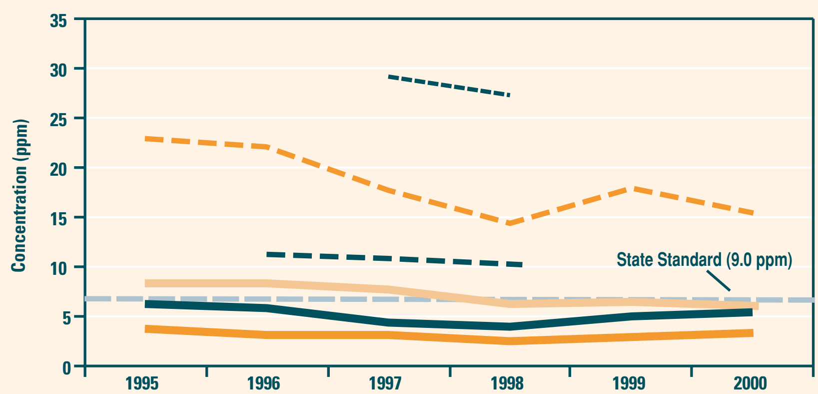
Peak concentrations of inhalable particulate matter (PM10), ozone, and carbon monoxide continue to exceed California air quality standards in the border region.

Type I
Level 4
Goal 1

Peak PM10 Concentrations
24-hour average



Peak Carbon Monoxide Concentrations
8-hour average



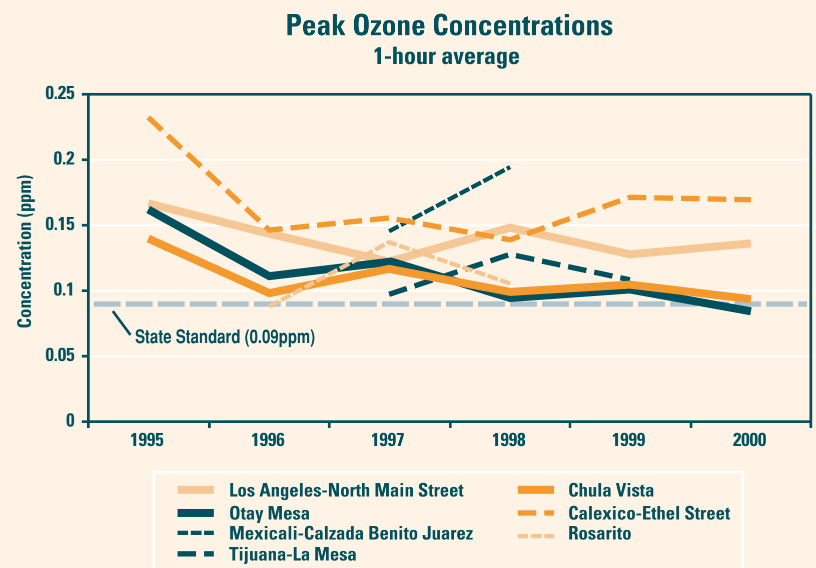
Source: California Air Resources Board

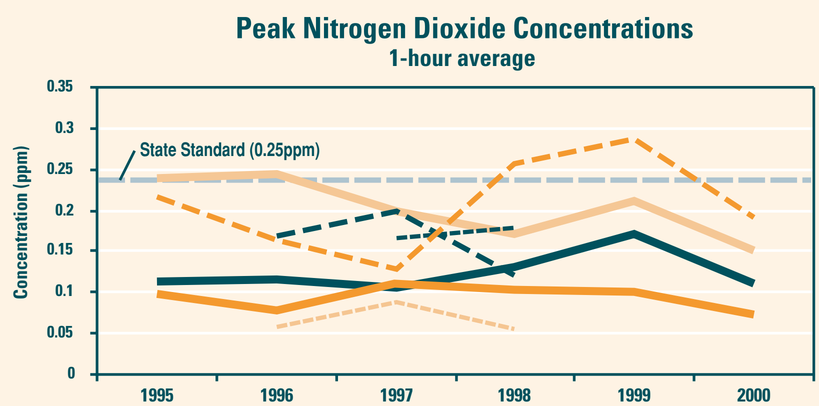
What are the indicators showing?

Cross-border air quality monitoring has been conducted in the San Diego/Tijuana region since 1995 and in Calexico/Mexicali since 1997. Data from monitoring stations at these cities show that concentrations of inhalable particulate matter (particulate matter 10 microns in diameter and less, or PM10) exceed the California State standard . Carbon monoxide concentrations exceed the state standard at Mexicali, Calexico, and Tijuana. Ozone peak 1-hour concentrations show exceedances of the state standard at all the stations in the border region with a downward trend for the California cities. The nitrogen dioxide (NO_2) standard was exceeded in Mexicali in 1998 and 1999, but all cities were in attainment in 2000. Data for one monitoring station in Los Angeles (located north of the border region) are presented to give a perspective to the air levels reported for the border communities. Monitoring data are not available for certain years at some sites.

Why is this indicator important?

The California/Baja California, Mexico border region is defined as the area within 100 kilometers (62 miles) of either side of the international border. The larger cities within the border region lie within common air basins, hence, both countries share responsibility for the impacts of air pollution. San Diego (Chula Vista and Otay-Mesa air monitors) on the coastal California side, and Tijuana and Rosarito on the Mexican side can be considered sister cities. Likewise, on





Source: California Air Resources Board

the eastern side of the state, Calexico (in California) and Mexicali (in Mexico) can be considered twin cities and actually are separated by only a city street. Attainment of air quality standards in the region requires the reduction of air pollutants on both sides of the border. The indicators will track trends in air quality in the border region in the face of growing urban populations and further industrialization.

What factors influence this indicator?

The San Diego-Tijuana area is situated along the Pacific Coast and is strongly influenced by ocean breezes. The majority of the time, daytime winds are from the west and nighttime winds are from the east, with slight variations. Daytime winds are usually much stronger than those at night and tend to blow the air pollutants from the urban areas inland.

Carbon Monoxide Count of Days Exceeding Statewide 8 Hour Standard (9.0 ppm)						
Station	1995	1996	1997	1998	1999	2000
Los Angeles-North Main Street	0	0	0	0	0	0
Chula Vista	0	0	0	0	0	0
Calexico-Ethel Street	17	11	13	10	13	7
Mexicali-Calzada Benito Juarez			42	59		
Otay Mesa	0	0	0	0	0	0
Rosarito		0	0	0		
Tijuana-La Mesa		3	4	1		

PM10 Calculated Days Exceeding State 24 Hour Standard (50μg/m³)					
Station	1995	1996	1997	1998	1999
Los Angeles-North Main Street	84	66	90	66	114
Chula Vista	30	12	12	0	12
Calexico-Ethel Street	201	246	294	234	264
Mexicali-Calzada Benito Juarez			120	108	162
Otay Mesa	114	90	126	108	126
Rosarito		132	276	210	276
Tijuana-La Mesa		189	252	189	204

Ozone-Count of Days Exceeding State 1 Hour Standard (0.09 ppm)					
Station	1995	1996	1997	1998	1999
Los Angeles-North Main Street	38	24	6	17	13
Chula Vista	7	1	10	2	4
Calexico-Ethel Street	38	44	24	25	38
Mexicali-Calzada Benito Juarez			20	18	
Otay Mesa	17	6	7	0	1
Rosarito		0	4	2	
Tijuana-La Mesa		1	15	2	

Source: California Air Resources Board

Climatic conditions in Calexico and Mexicali are characterized by winds that blow most often from the west and northwest. However, during the summer months the direction shifts dramatically and the wind blows from the southeast.

PM10, ozone, and carbon monoxide can exacerbate respiratory problems, including asthma and decreased lung function. Air standards for these pollutants are intended to protect human health. Ozone is formed by the photochemical reaction of sunlight with certain air pollutants, such as volatile organic compounds and nitrogen oxides. These pollutants are emitted from motor vehicles as well as industrial sources.

PM10 particles originate from mechanical activities, windblown dust, combustion sources, and chemical reactions in the atmosphere. Field studies have shown that the major component of PM10 in the Calexico/Mexicali region is directly emitted dust, such as from unpaved roads.

High carbon monoxide concentrations can be seen on the Mexican side of the border because the vehicle fleet consists primarily of older cars. Due to lack of maintenance and the absence of requirements for smog check inspections, the emission controls of these vehicles are often deteriorated, resulting in greater carbon monoxide emissions. Although California reformulated gasoline is widely used in the Mexican border region, the use of Mexican fuels may increase tailpipe emissions.

Oxides of nitrogen (NOx) contribute to the formation of ozone. The main sources of NOx are motor vehicles and industrial combustors. New power utilities are being constructed in Rosarito, Tijuana and Mexicali and it is expected that emissions of NOx will increase as a result.

The air quality measurements at an air monitoring site are representative of the levels of air pollutants in the general neighborhood of the monitoring station. Thus, the Otay-Mesa station, located among the complex of buildings that make up the Otay-Mesa border crossing, provides an indication of ozone levels in the southern tier of San Diego County, as well as the northernmost part of the city of Tijuana.

The monitoring network in the border region has increased significantly in the past few years. Increases in peak concentrations during this period may be misleading since additional monitors (in additional locations) provide more opportunities to measure poor air quality. Confidence in this indicator should improve as more data are accumulated.

Reference:
California Air Resources Board, California Air Quality Data, www.arb.ca.gov/aqd/aqd.htm

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Technical Considerations:

Data Characteristics

The data presented are representative in general of only one air monitoring station at each city. However, most of the areas have several monitoring stations. All the data presented meets quality assurance standards of the California Air Resources Board and the U.S. Environmental Protection Agency for air monitoring. Monitoring data were not available for certain years at some sites.

Strengths and Limitations of the Data

The ambient air concentrations of these pollutants were accurately measured and recorded. Information from each individual station is indicative of pollution levels in the general neighborhood of the monitoring station. However, data from multiple stations are needed to obtain a comprehensive view of the air quality in that region.

Although the discussion has focused on the criteria pollutants (PM10, carbon monoxide, ozone, and NO_2), toxic air contaminants (TACs) are also measured in the border region. Common TACs are solvents, metals, and hydrocarbons emitted from the combustion of petroleum products and manufacturing processes. Typical TAC emission sources may be service stations, dry cleaners, electroplating industries, electronics manufacturing facilities, and paint shops. TACs are measured at Chula Vista, El Cajon, Calexico, Mexicali and Rosarito. The TAC monitoring data can be viewed at: www.arb.ca.gov/aqd/almanac01/chap601.htm.

Ballast Water Program

Type III

Ballast water discharged from United States and foreign vessels visiting California ports has been responsible for the introduction of non-indigenous aquatic species (NAS) into the state's waters. As world trade and travel have increased, the invasion rate of new aquatic species has grown exponentially (Cohen, 1998). After ships discharge their cargo, they take on ballast water from the local port to provide stability before going to sea again. Often the ballast waters and sediments are rich in organisms such as viruses, bacteria, protozoa, seaweed, algae, fungi, plants, and fish, which are then transported and released in other areas of the world. Some NAS have displaced native plants and marine life, and have caused economic, human and ecological health impacts (United States Congress, 1993).

To prevent new introductions of NAS into the state, the California Ballast Water Management Act of 1999 (Act) (Public Resources Code Section 71200) requires vessels to exchange ballast water mid-ocean to reduce the density of organisms in ballast tanks. The California State Lands Commission (CSLC) enforces the requirements of the Act through an active inspection program, which targets approximately 25 percent of qualifying ship arrivals. Ballast water from vessels is analyzed for saline content to verify that it originated from mid-ocean sources and is not brackish from coastal ports. Ninety-two percent of inspected vessels were found to be in compliance with the Act during the first year of the program.

Mid-ocean ballast exchange reduces the amount of foreign coastal marine organisms deposited in California waters, but it may only eliminate 55 to 67 percent of the original species entrained in the ballast water due to tank design and organisms that reside in bottom sediment (Greenman, 1997). In the summer of 2001, the Port of Oakland and Smithsonian Environmental Research Center initiated a study on the effectiveness of ballast exchange in reducing the introduction of NAS. As part of the study, an inventory of hull and ballast water organisms on arriving ships will be created. Additionally, the CSLC, with funding from the United States Fish and Wildlife Service and the Port of Oakland, will retrofit two volunteer commercial vessels in the fall of 2001 with ballast water treatment systems. The State Water Resources Control Board will evaluate the effectiveness of these systems, in collaboration with the CSLC, United States Coast Guard and Smithsonian Environmental Research Center.

Also as part of the mandates of the Act, the Office of Spill Prevention and Response of the California Department of Fish and Game is conducting an inventory of NAS populations in coastal and estuarine waters to establish indigenous baseline populations. Reports required under the Act are due to the Legislature in December 2002. The information presented in these reports may be used to craft a new, long-term program, which could be adopted before the current law expires on January 1, 2004.

The Ballast Water Program may eventually include biota evaluations of selected species and, coupled with saline inspections, provide an indicator of NAS introductions and effective treatment measures.

References:

California's Ballast Water Management Act. Section 1, Division 36 (commencing with Section 71200), Public Resources Code.

Cohen, Andrew N. and Carlton, James. *Accelerating Invasion Rate in a Highly Invaded Estuary.* Science 279(23):555-558. January, 1998.

Greenman, D., Mullen, K., and Parmar, S., 1997. *Ballast Water Treatment Systems: A Feasibility Study.* Aquatic Nuisance Species (ANS) Task Force Reports and Publications. Washington, D.C. Project Center.

Ballast Water Program, State Lands Commission, posted at bear.slc.ca.gov

United States Congress, Office of Technology Assessment, *Harmful Nonindigenous Species in the United States*, 1993.

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