The Asian Continental Aerosol Plume: Impacts on California

Richard VanCuren, Ph.D.

ARB Research

January 22, 2004

Thank you Ms. Witherspoon.

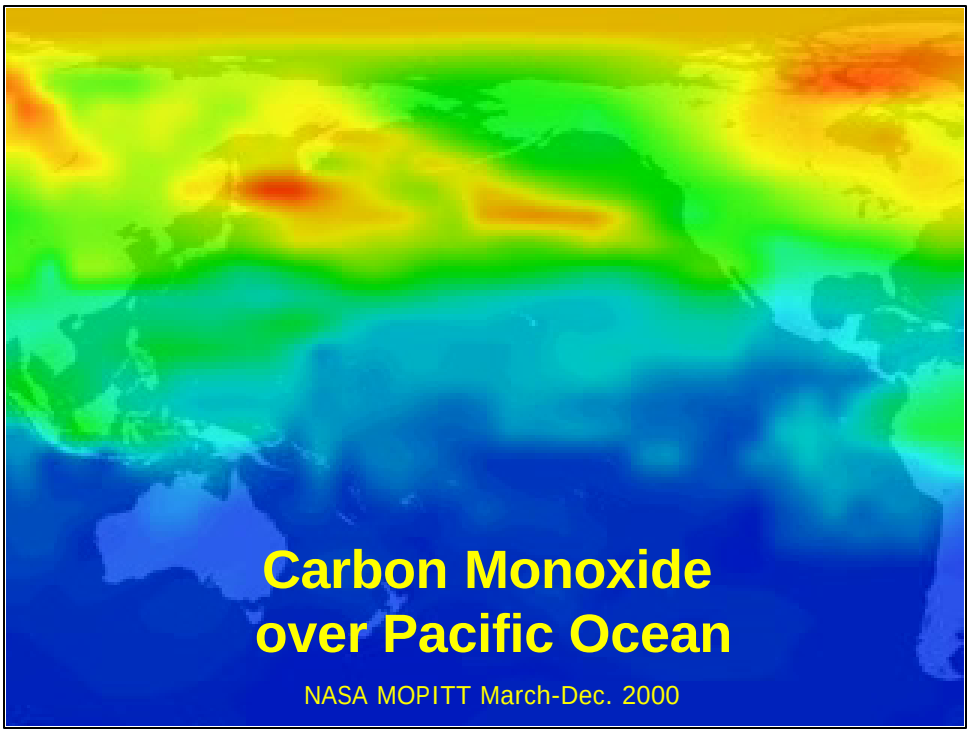
Chairman Lloyd, members of the Board. This presentation is about global-scale pollution, but we offer it today as an “health update” because we want to highlight the connections between what is occurring globally and here in California.

In recent years ARB has made a significant effort to share our technical expertise with our Pacific Basin neighbors and to promote adoption of advanced pollution control methods worldwide. The research I am reporting to you today makes that effort even more urgent.

When we started studying air pollution in the middle of the last century, it was universally seen as a local problem of industrial and urban areas.

Today we are on the brink of an enormous global economic transformation in which hundreds of millions of people will move from traditional livelihoods to modern energy-intensive lifestyles. The environmental consequences of this change are only dimly foreseen, but one thing is becoming clear - in the future we will all live downwind of one another, and we will need to adjust our thinking accordingly.

In the next few minutes I will summarize my recent research into measuring how much Asian particulate air pollution impacts California.



Satellites provide global coverage and give us a unique view of global pollution.

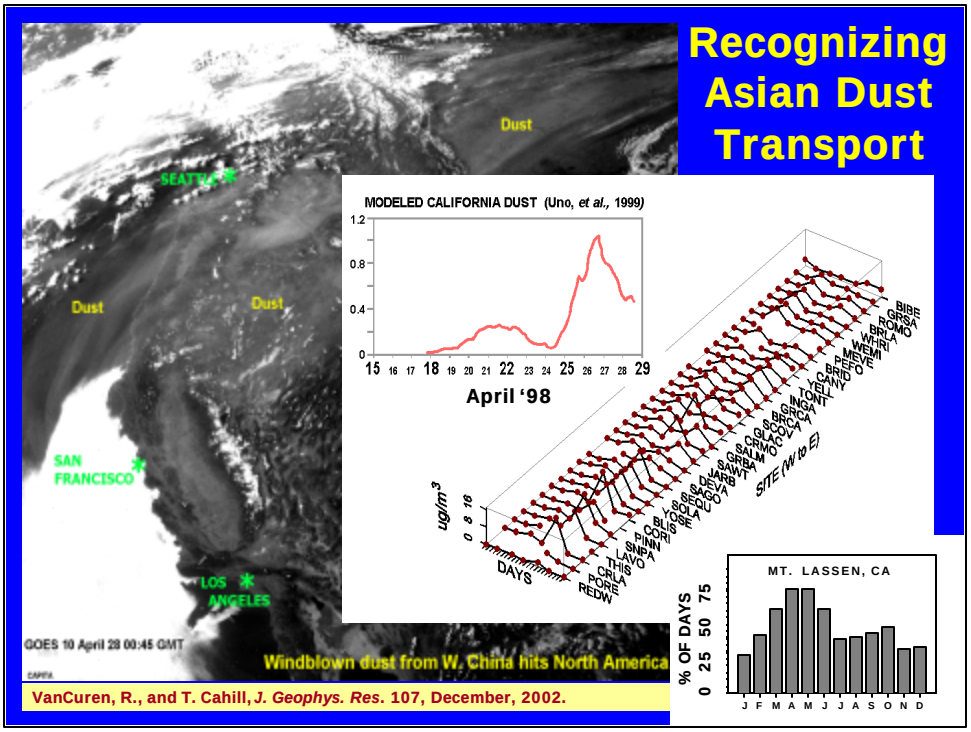
This animation shows satellite measurements of carbon monoxide (CO) over the Pacific Ocean for March to December 2000. CO comes from biomass burning and the use of fossil fuels and is a general tracer for anthropogenic pollution. The underlying map shows the oceans as deep blue, the continents as light blue. CO concentrations are shown increasing from pale green to deep red. This animation shows the movement of gaseous CO, but particles follow much the same paths.

As this animation runs, I'd like to point out two major features:

First, there is much more CO in the northern hemisphere than in the southern - an obvious effect of the concentration of human population.

Second, we see obvious hotspots associated with the major population centers such as China or eastern North America, and areas of intense biomass burning such as Indonesia and equatorial South America.

The flow of pollutants across the North Pacific from Asia to California is obvious in this animation, but it has been elusive to measure on the ground.



In April of 1998 there were two enormous dust storms generated over the Takla Makan and Gobi deserts of northern China. These dust clouds were readily visible in weather satellite images, widely noted in the press, and written up in scientific journals. These dust events were generally regarded as "freak" occurrences.

However, when I looked at the weather data for these events it became clear that, although the dust was unusual, the overall wind patterns were not, so I decided to search historical PM sampling records for previous episodes of Asian dust.

The top graph shows the modeled dust load over California for the last two weeks in April 1998.

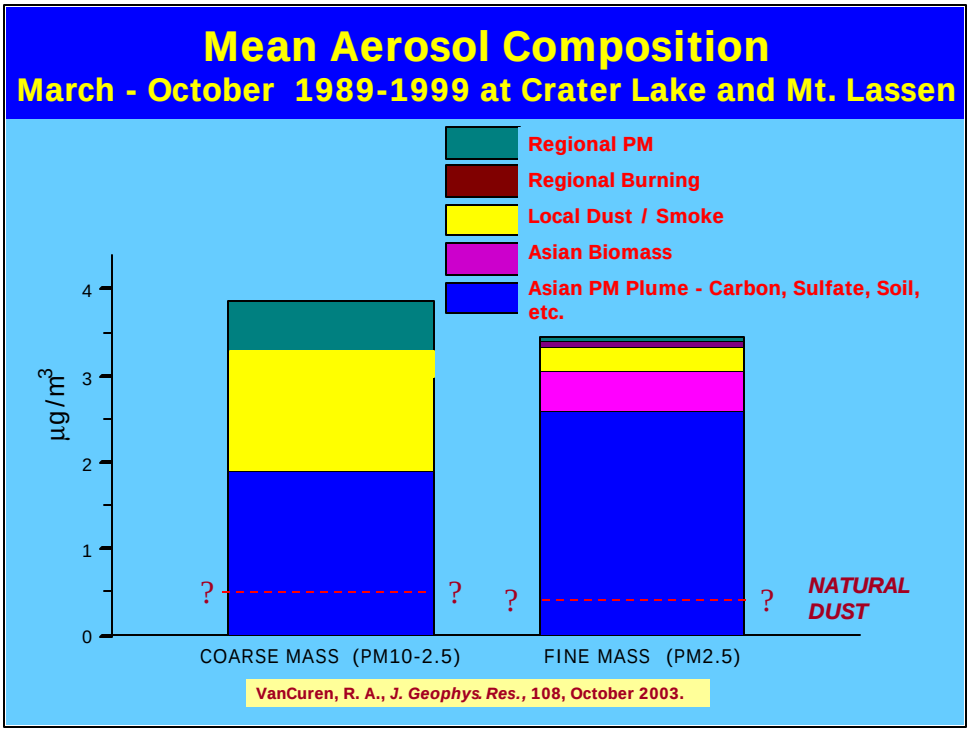
The box diagram shows how that same curve appears in the records from twice-weekly sampling at 36 IMPROVE monitoring sites at National Parks and Wilderness areas in the western U.S. The data are arranged from west to east, and you can see the two-hump pattern repeated at each site as the dust clouds moved across the continent.

Analyzing the 1998 events I found a distinctive chemical profile for the Asian dust, and then used that profile to search the entire decade of IMPROVE data.

To my surprise, I found that small amounts of Asian dust (about 1/2 ug/m3) were common at IMPROVE sites across the West, and occasionally detectable even on the east coast. The bottom right plot is monthly Asian dust frequency for Mt. Lassen for the decade 1989-1999.

Clearly, the pattern of nearly continuous transport suggested by the CO data on the previous slide is mimicked by the dust.

Our paper in the *Journal of Geophysical Research* in December, 2002 was the first to use ground observations to show the persistence of transPacific transport.



The dust was easy to find in the IMPROVE records due to its unique chemistry, but it only accounted for a small fraction of total PM in the samples. Using the dust as a marker for Asian air masses I was subsequently able to identify what other material accompanied the dust.

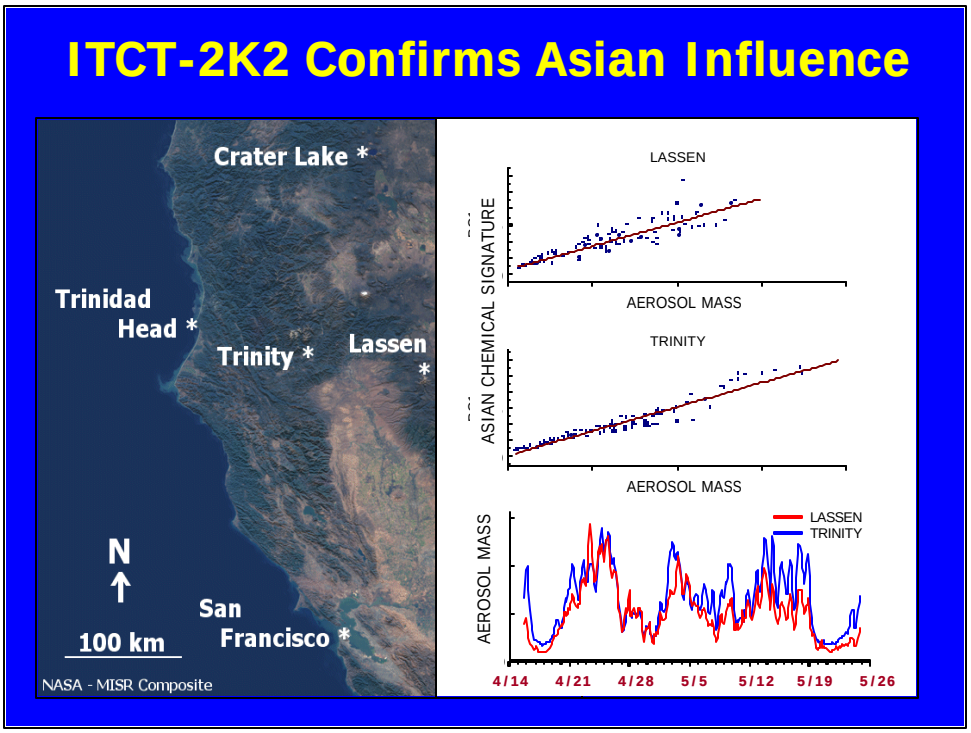
The Asian material was easiest to recognize at Crater Lake, OR and Mt. Lassen, CA, which have the least exposure to North American pollutants of any IMPROVE sites. Using statistical methods I was able to identify groups of pollutants that vary together and classify them into categories such as local road dust, fires, and the dusty Asian plume.

Averaged over the months March through October for the decade 1989-1999, PM from Asia constitutes about 2/3 of the total PM10 at Crater Lake and Mt. Lassen, and more than 4/5 of the fine material (PM2.5). The Asian PM plume is roughly half carbonaceous and about 1/4 each dust and sulfate.

Although it is difficult to accurately define how much dust is “natural,” the fact that it comes almost daily means that windblown dust is only a small portion of the total dust load - the rest is due to human activity in Asia, such as farms, dirt roads, and such.

At roughly 5 ug/m3 PM10 and about 3 ug/m3 PM2.5, the Asian material alone is roughly 1/4 of the California annual average PM10 and PM2.5 standards.

These findings were published last October in the *Journal of Geophysical Research.*



The analysis of the IMPROVE data showed that Asian PM is a major component of the "background" over California. However, IMPROVE's intermittent sampling schedule left some questions unresolved.

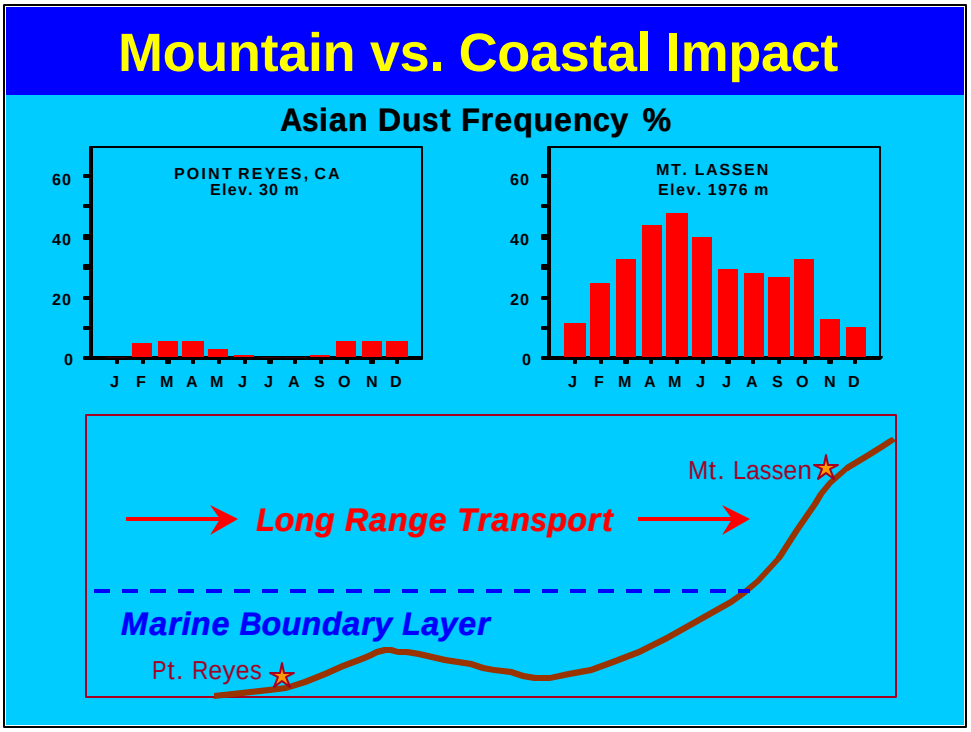
In spring of 2002, an international consortium of researchers conducted the 2002 Intercontinental Transport and Chemical Transformation Study. Dr. Steven Cliff of UC Davis collected continuous aerosol samples for 6 weeks at Trinidad Head and two elevated inland sites - Trinity Alps and Mt. Lassen.

Although we saw abundant oceanic PM at Trinidad Head, it was insignificant at the mountain sites. Conversely, we saw virtually continuous Asian influence at the mountain sites.

The top two plots show that during this experiment the Asian component explained virtually all the PM at Trinity and Mt. Lassen.

Moreover, as shown in the bottom plot, these mountain sites tracked one another closely over the entire sampling period, emphasizing that we were seeing a broad regional pattern, not local PM.

The IMPROVE data showed that small amounts of Asian dust are ubiquitous at mountain sites in the West; these data showed that Asian transport is nearly continuous.



The fact that Asian transport is strongest at mountain sites shows the importance of layering in the atmosphere over the Pacific and coastal North America.

The result is that the impact is smaller at low altitude coastal sites than in the mountains.

The upper plots show monthly Asian dust frequency at Point Reyes (left) and Mount Lassen (right). The dust is relatively rare at Point Reyes, but common at Mount Lassen.

The bottom diagram illustrates how the inversion layer created by cool, stable air over cold ocean water prevents Asian impact along the coast. Air coming across that Pacific above the marine layer is prevented from reaching sea level, and the coastal site records very little Asian effect.

Because surface inversions prevent mixing with overlying air, we believe that Asian material is generally precluded from mixing with trapped pollutants during high pollution episodes in populated areas such as the San Francisco Bay area, South Coast, or San Joaquin Valley.

Thanks to this effect, Asian transport is not likely to exacerbate our problems on high pollution days, but it will have a small effect on annual average PM concentrations.

Findings

- Some Asian dust is natural - not itself a major problem
- Dust is accompanied by biomass smoke, agricultural dust, motor vehicle and industrial emissions
- Average Asian aerosol load at mountain sites is about 1/4 of CA PM10 and PM2.5 standards; 1/5 and 1/10 or Federal PM10 and PM2.5 standards.
- Asian aerosols can be a major component of PM in otherwise "clean" rural sites.
- Asian aerosols are a minor component of PM in heavily polluted areas, and the same conditions that trap pollutants near the ground preclude Asian PM from contributing to peak PM concentrations.

The findings of this research are these:

Transport of Asian dust is a frequent and natural process.

However, the dust today is accompanied by anthropogenic emissions.

The average Asian aerosol load at elevated sites is small, about 1/4 of California's stringent PM10 and PM2.5 standards.

In rural areas in California that are relatively pollution-free, especially mountain sites, Asian aerosols are a major component of PM.

In the populated lowland areas where most Californians live, Asian pollutant impacts are limited, and do not appear to contribute to high concentration events.

Implications

- Typical low concentrations are a "floor" for PM concentrations
  - Only a small contribution to human exposure
  - Needs to be considered in Regional Haze programs
- Rare high concentrations (e.g. 1998 dust storms) may exceed PM standards
  - Low frequency (once a decade?) has little health significance
  - Need to be recognized as exceptional events
- Asian emissions may grow with economic expansion
  - Need to improve understanding and track changes

The implications of Asian PM transport for California's air programs are these:

The average Asian aerosol load at elevated sites is small relative to health-based air quality standards; it does not appear be a major health concern.

Because Asian PM dominates background PM at some sites, it needs to be explicitly considered in our Regional Haze analyses.

High concentrations, such as the 1998 dust storms may cause or contribute to violating health-based air quality standards, but such events are very rare (perhaps once a decade). However we need to be aware of these and deal with them as "exceptional events".

In the past we have offered our expertise to our Pacific Rim neighbors as a gesture of good will to neighbors and trading partners; we now see that technology transfer also serves our own air quality goals as well.

For the time being, the Asian PM impact is a minor problem for California; we hope that Asian pollution controls will evolve rapidly, compensating for the expected growth. Just to be sure, we will continue to monitor this problem.

Thank you for your kind attention, and I will be happy to answer any questions.