California 2010 CalNex and the Downwind WRAP Region Field Study White Paper
DRAFT January 7, 2009 DRAFT

Background

Studies of regional haze in the Western United States have shown that sources and source categories form aerosols measured at ground level as ambient Particulate Matter (PM, measured as sulfate, nitrate, organic and elemental carbon, dust and geogenic material, mercury, sea salt), and ozone (O3, NOx and related Nitrogen species, Volatile Organic Compounds [VOCs] or Reactive Organic Gases [ROG]); transport of those aerosols then ranges from tens to thousands of kilometers. These aerosols flux between gas and particulate phase, impacting both rural and urban areas, affecting primary air quality health standards (ozone and PM National Ambient Air Quality Standards [NAAQS]), as well as secondary air quality welfare standards (ozone and PM NAAQS, Regional Haze Rule). The sources affecting the more than 100 relatively clean Class I Federal areas in the West are affected by sources ranging from global to regional to local scales. With the announcement of the effort to plan the 2010 CalNex field study by the California Air Resources Board (ARB) and the National Oceanic and Atmospheric Administration (NOAA), the WRAP Technical Committees and Forums are reviewing the opportunity to leverage and extend the field study effort in 2010 within California to the downwind WRAP region (http://www.wrapair.org/about/0309wrapmap.pdf).

Starting with the current 2010 CalNex Field Study science questions (http://www.arb.ca.gov/research/fieldstudy2010/questions_feb2009.htm), the WRAP has prepared a working draft of related science questions for the downwind WRAP region, shown in Appendix A. In Appendix B, a NOAA Chemical Science Division write-up of “Longer-range transport of California emissions affecting downwind areas” is included. WRAP has met with staff from the NOAA CSD and the CARB Research Division to develop the concept of an extended and leveraged 2010 Field Study.

2010 CalNex Planning Meeting

The Research Division of CARB and NOAA is holding a two day planning meeting in February 2009 for the 2010 CalNex California field study, which will target scientific issues related to both air quality and climate change. The purpose of the meeting is to share information about the goals and planned field efforts and to provide a forum for discussion of coordinating CalNex with other work that will occur in 2010. The meeting will be held in the CalEPA building in Sacramento on Thursday February 5th from 9:30 AM to 5:00 PM, continuing on Friday February 6th from 9:00 AM to 1:00 PM. For further information, see: http://www.arb.ca.gov/research/fieldstudy2010/fieldstudy2010.htm

Next Steps for the WRAP

Representatives from the WRAP will attend the February 2009 CalNex Study planning meeting to present the downwind WRAP region science questions in Appendix A, and discuss the extension of the study beyond California. Likely next steps for the WRAP members, assuming support for the extended study region by CARB and interest by NOAA in extending the aloft measurements east of California, include:

- Develop an ambient monitoring plan (site location, instrumentation, operators, and data collection);
- Identify funding resources – both needs and potential funding sources;
- Specify additional activity and emissions data collection efforts during the field study by source category; and
- Develop potential complementary WRAP region air quality data analysis and modeling plan to align with CARB and NOAA efforts.

Appendix A: Regional Field Study Science Questions – Revised Draft of 1/7/09

CalNex 2010 Science Questions - from: http://www.arb.ca.gov/research/fieldstudy2010/questions_feb2009.htm	**Downwind WRAP Region Science Questions**
Emissions	***Emissions***
A. How can we improve the emissions inventory for greenhouse gases, ozone and aerosol precursors including emissions from soil, ships, agriculture and other non-industrial or transportation related processes? What measurements can help validate the use of satellite data for biogenic VOC and NOx emission inventories?	**A. Same question, focus on ozone and aerosol precursors more than GHGs?** Emphasis on soil, agriculture, energy production, and fire sources. Identify and test satellite data detection of these sources, coordinate with NASA grant projects through ROSES program.
B. What emissions (natural and anthropogenic) and processes lead to sulfate formation over California coastal waters and in urbanized coastal areas? What is the contribution from ship emissions? How does Southern California compare and contrast with the San Francisco Bay Area?	**B.1. What emissions** (natural and anthropogenic) and processes lead to the nitrogen and organic aerosol flux and ozone formation and transport in Class I areas across the WRAP region? What is the contribution from intercontinental, eastern Pacific Ocean, and California land-based emissions? How does the southern WRAP region (south of 42° N latitude) compare and contrast with the northern WRAP region?
	B.2. What emissions (natural and anthropogenic) and processes lead to the geologic dust flux and transport to Class I areas across the WRAP region? What is the contribution from intercontinental and California land-based emissions? How does the southern WRAP region (south of 42° N latitude) compare and contrast with the northern WRAP region?
C. What sources and processes contribute to atmospheric mercury concentrations in California?	**C. What sources and processes contribute to atmospheric mercury** concentrations across the WRAP region?
Chemical Transformation and Climate Processes	
A. How important are chemical processes occurring at night in determining transport and / or loss of nitrogen oxides, reactive VOC and ozone? Do regional models in California adequately represent these processes and their effect on air quality?	**A.1. 1 How important are chemical processes** occurring at night in determining transport and / or loss of nitrogen oxides, reactive VOC and ozone to receptor sites in the downwind WRAP region? **A.1.2 Do regional models across the WRAP region,** including California, adequately represent these processes and their effect on air quality?

	A.2.1. How important are sources and sinks of nitrogen oxides, reactive VOC and ozone to the chemical processes occurring during transport to receptor sites in the downwind WRAP region? **A.2.2. Do regional emissions and air quality models across the WRAP region,** including California, adequately represent these processes and their effect on air quality?
B. What are the sources and physical mechanisms that contribute to high ozone concentrations aloft that have been observed in Central and Southern California?	**B. What are the sources and physical mechanisms** that contribute to high ozone concentrations at high elevation monitoring sites across the downwind WRAP region?
C. Are there significant differences between Central Valley and South Coast Air Basin precursors or ozone formation chemistry? Will meteorological and/or precursor differences between the Central Valley and the South Coast Air Basin lead to different chemical transformation processes and different responses to emissions reductions? What is the importance of natural emissions to the ozone formation process? Are there regional differences in the formation rates and efficiency for particulate matter as well?	**C. Are there significant differences between precursors or ozone formation chemistry in selected rural and urban areas in the downwind WRAP region?** Will meteorological and/or precursor differences between these selected rural and urban areas lead to different chemical transformation processes and different responses to emissions reductions? What is the importance of natural emissions to the ozone formation process? Are there regional differences in the formation rates and efficiency for particulate matter as well?
D. What are the impacts of aerosols in California on radiative forcing and cloud formation? What are the most important precursors and formation processes for secondary organic aerosol? What is the role of aqueous phase processes in atmospheric transformations?	?
Transport and Meteorology	
A. What are proper oceanic boundary conditions for coastal and regional atmospheric chemistry modeling? Are there variations in oceanic boundary conditions in northern and central California vs. the southern part of the state? What physical and chemical changes occur as a parcel of air moves from off-shore, through the shore zone, and inland?	?
B. How best can we characterize and model air flow over coastal waters and the complex terrain of California? For example: what is the best representation of air flow in the southern San Joaquin Valley, particularly with respect to flow between the San Joaquin Valley and South Coast Air Basin versus recirculation north along the Sierra Nevada and Coastal ranges?	**B. How best can we characterize and model air flow** over the complex terrain of the downwind WRAP region? *Provide examples for discussion?*

C. What are the major deficiencies in the representation of chemistry and meteorology in research and operational models and how can models be improved through the collection of additional measurements? What physical and chemical processes are not captured well by available models? Is there an optimum grid resolution to capture all of the relevant physical and chemical processes that occur?	**C. What are the major deficiencies in the representation of chemistry and meteorology in research and operational models** and how can models be improved through the collection of additional measurements? What physical and chemical processes are not captured well by available models? Is there an optimum grid resolution to capture all of the relevant physical and chemical processes that occur?
D. What are the important transport corridors for key chemical species and under what conditions is that transport important?	**D. What are the important transport corridors for key chemical species** and under what conditions is that transport important?
E. What is the relative roles of regional (North American) sources and long range transport (from East Asia) on aerosol forcing over California?	**E. What is the relative roles of regional (North American) sources and long range transport (from East Asia) on aerosol forcing over the downwind WRAP region?**

Appendix B - Longer-range transport of California emissions affecting downwind areas

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Longer-range transport
The composition of the atmosphere over California is affected by transport of emissions from upwind sources into the state. Similarly, the atmospheric composition over downwind regions is affected by transport of California emissions out of the state. Discussed below are three aspects of these reciprocal transport issues that will be investigated during CalNex 2010.

5.4.1 U.S.-Mexico Air Quality Issues.
Northern Mexico is generally sparsely populated, with the majority of the people living in the U.S.-Mexico border region, which comprises 14 pairs of inter-dependent "sister cities" containing 90% of the 14 million border area residents. The population and industrial development in this region are expected to increase dramatically in the coming decades. In 1983 the U.S. and Mexico signed the La Paz Agreement, which was intended to lead to binational cooperation for the protection and improvement of the environment in the border zone as defined in Figure 5.4.1.

From both the Mexico and California points of view, it is expected that air quality issues will be associated with air masses originating in the portion of the border region adjacent to California, which includes two of the sister city pairs (Tijuana-San Diego and Mexicali-Imperial Valley) that have the most significant air pollution problems.

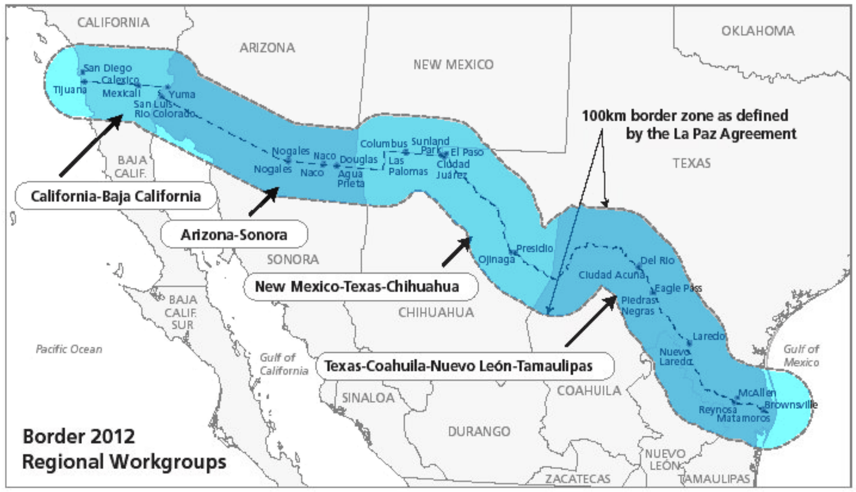

Figure 5.4.1 Map of the U.S.-Mexico border

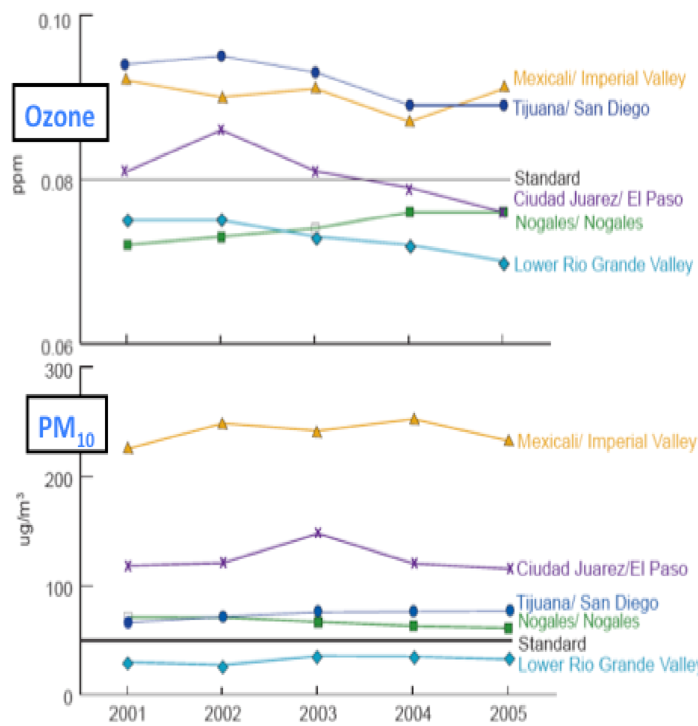

Figure 5.4.2 Average of 4th highest ozone concentration and highest three-year average of annual mean aerosol concentration for the more polluted border region areas (adapted from Border 2012, 2005).

Figure 5.4.2 compares the ozone and aerosol

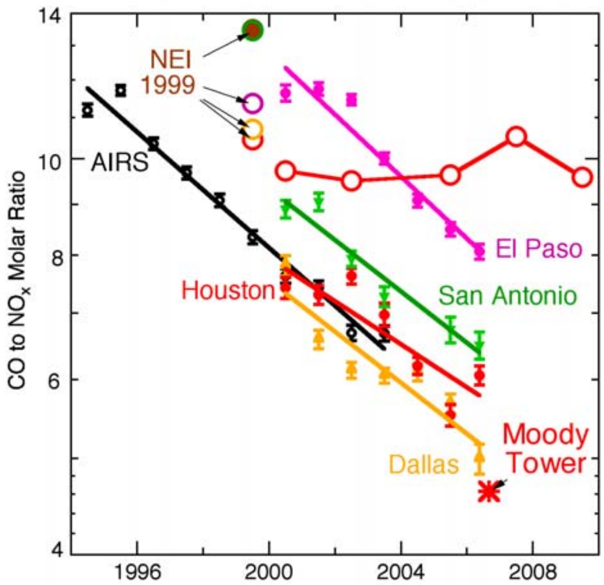

Figure 5.4.3. CO to NO_x ratio in on-road mobile emissions from monitoring data (solid symbols) compared to the emission inventories (open symbols), color-coded according to urban area. The black symbols are for all stations in the EPA AIRS network.

concentrations observed in different urban areas of the border region. The two California border regions account for the highest observed ozone and aerosol concentrations. Both of these pollutants are found at concentrations above the U.S. NAAQS in both areas.

It is also expected that the composition of the emissions in the border regions will be different from that observed in other areas of either country. Figure 5.4.3 presents an example (TCEQ, 2007). The on-road vehicle emissions in El Paso (one of a pair of border sister cities) differ significantly from other Texan urban areas. This difference is attributed to emission standards and vehicle fleets, which differ between El Paso and its Mexican sister city, Juarez. Differences are also expected in point source emissions, since US and Mexican emission standards for these sources also vary.

CalNex 2010 will conduct two investigations related to these US-Mexico air quality issues. First, cross border flights of the WP-3D aircraft will be conducted to determine if the differences in emissions (mobile sources, point sources) on the opposite sides of the border reflected in differences in atmospheric chemistry, such as ozone production efficiency, or aerosol composition or concentrations. Second, the results of these cross border aircraft flights will be combined with transport modeling to determine the balance and effects of cross-border transport of atmospheric pollutants between California and Northern Mexico.

5.4.2 Effect of intercontinental transport of Asian emissions into California.

East Asia is the heavily industrialized continental region most immediately upwind of California, but it lies approximately 9000km away on the western side of the North Pacific Ocean. Emissions of ozone and aerosol precursors from East Asia have increased rapidly over the past decade, and thus increasing impacts of transported Asian emissions on US air quality may be expected. However, quantification of these impacts is difficult. Figure 5.4.4 shows that spring and summer time ozone concentrations in air arriving at the US west coast form the Pacific marine boundary layer (MBL) have increased substantially over the past two decades (Parrish et al., 2008). Positive trends are also seen in fall and winter. It is tempting to attribute these increases to the increasing Asian emissions, but very similar trends are seen at Mace Head, Ireland, which is much more remote from the Asian emissions.

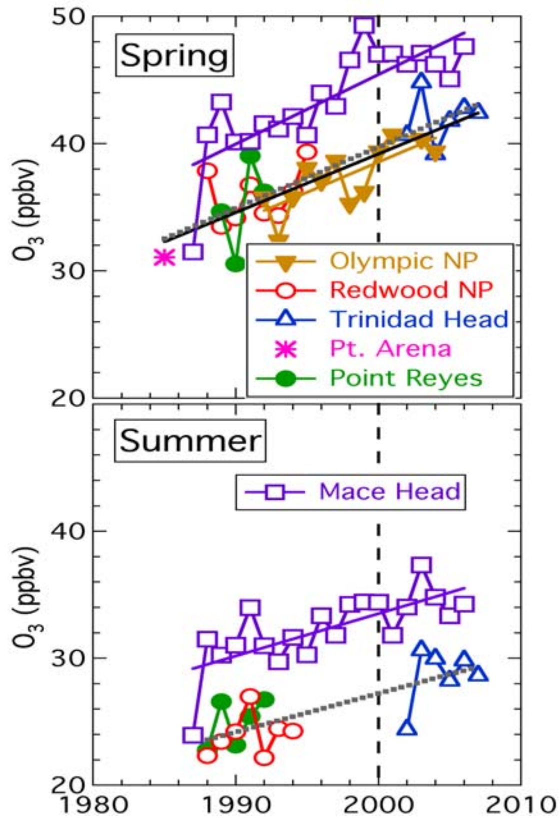

Figure 5.4.4. Comparison of trends in MBL ozone concentration at the US Pacific Coast and Mace Head, Ireland.

Figure 5.4.5 illustrates an analysis that provides a diagnosis of the photochemical environment to which air masses are subjected over the Pacific Ocean during their transport from Asia to California. Data are shown from three field studies conducted at the Pacific Coast of North America over a span of 21 years, all in springtime. In this plot the x-axis represents degree of photochemical aging of the sampled air masses. Since propane reacts more rapidly in the atmosphere than does ethane, the ratio of these two hydrocarbons decreases as fresh emissions are aged in the atmosphere. During the earliest study in 1985 at Pt. Arena it was found that ozone concentrations were lower in more aged air masses (to the left in Fig. 5.4.5). This relationship indicates that the environment over the Pacific Ocean lead to relatively rapid photochemical destruction of ozone during this early study. In contrast, during the later 2002 study and 2006 studies, the ozone concentrations decreased to a much smaller extent with hydrocarbon aging. This behavior indicates that the photochemical environment of the troposphere over the Pacific Ocean changed in the two decades covered by the studies. One possible cause of this change is that increasing emissions of ozone precursors from Asia are responsible for greater rates of ozone production over the downwind Pacific Ocean.

The Research Vessel Ronald Brown and the WP-3D aircraft will collect data sets during CalNex 2010 that can be analyzed in the manner of Fig. 5.4.5. These data sets will present seasonal contrasts to the three earlier studies, or, if conducted in the spring, will provide a further increase in the temporal span covered by the analysis.

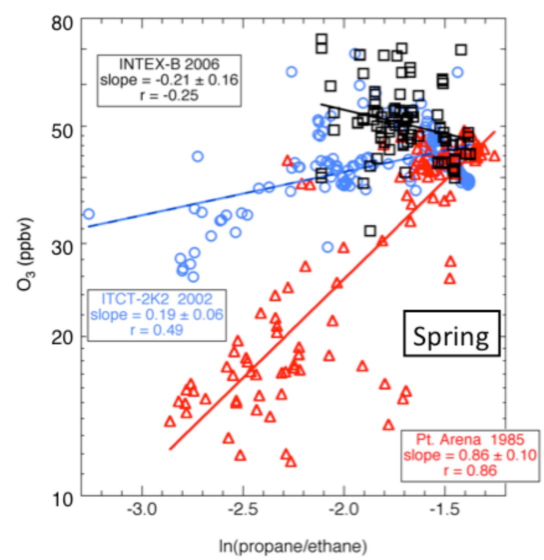

Figure 5.4.5. Relationships between O_3 concentration and the natural log of the propane to ethane ratio for MBL data sets (after figure from Parrish et al., 2004).

5.4.3 Transport of California emissions to downwind states.

Transport of pollutants from California to the downwind continental US has received particular attention with respect to the Class I visibility areas of the national parks and wilderness areas in the western US. Increasingly it is also recognized that ozone levels in the western US are increasing, and are approaching the new NAAQS of 75 ppbv, even in the most rural areas. Figure 5.4.6 shows the pattern of observed rural ozone concentrations in the western US. Although there are too few monitors to clearly define detailed spatial gradients, there is a clear indication that the highest ozone levels are found downwind from the major urban areas of California. This indication suggests a plume of ozone, transported from, and produced enroute from ozone precursors emitted in, California urban areas.

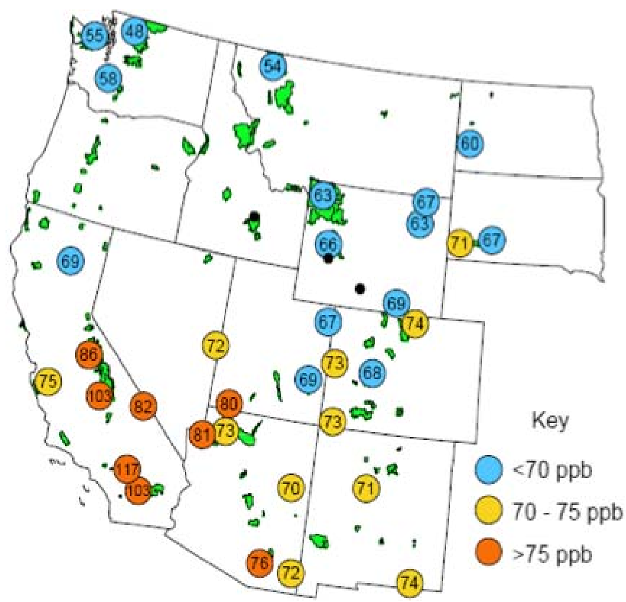

Figure 5.4.6. Non-urban ozone concentrations in the western US. 2004-2006 3-year average of the 4th highest daily maximum 8-hour average. Orange indicates violation of new 75 ppbv standard. (from Tom Moore, 2008).

Currently we have very little understanding of the mechanisms responsible for the interstate transport of California emissions and their photochemical products including aerosols and ozone. Four first order questions arise that will be addressed during CalNex:

- Is this transport most effectively thought of as slow, relatively constant leakage, or intermittent, rapid surges?
- Do the Sierras and other mountain ranges represent a transport barrier, or a transport mechanism (c.f. Fig. 5.4.7)?

These first two questions will be addressed by comparing observations from WP-3D flights with transport modeling.

- Do California emissions leak around the mountains through lower elevations?
- Can California emissions be directly observed at surface sites in downwind states?

The lidar aircraft can effectively investigate such transport pathways. Collaboration is being pursued with the Western Regional Air Partnership (http://www.wrapair.org/) and EPA funding to conduct such measurements.

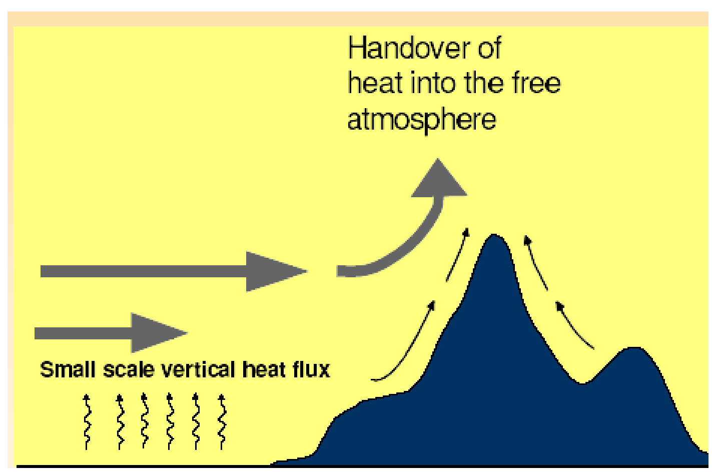

Figure 5.4.7. Schematic of different flow regimes contributing to the transfer of heat from the land surface to the free troposphere (from Summer School Trento, 17-23.08.2003, Lecture 4, Prof. Dr. F. Feder.

References:

Border 2012: US Mexico Environmental Program, Indicators Report, 2005. (Available from http://www.epa.gov/usmexicoborder/docs/BorderIndicatorsReportApril2006.pdf)

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