Session 2: Key contributions from observational campaigns: CalNEX/IONS, DISCOVER-AQ, San Joaquin Valley APCD-funded Chews Ridge research, etc.

Owen R. Cooper
CIRES, University of Colorado, Boulder
NOAA Earth System Research Laboratory, Boulder
1:00 p.m. - SESSION 2

Key contributions from observational campaigns: CalNEX/IONS, DISCOVER-AQ, San Joaquin Valley APCD-funded Chews Ridge research, etc.

Speakers

Owen Cooper, Research Scientist III, U. of Colorado/NOAA

David Parrish, Senior Research Scientist, University of Colorado/CIRES

Ian Faloona, Associate Professor, University of California, Davis

Salient Questions

1. What is the current observation-based evidence of the TAO contribution to free tropospheric ozone and to ground-level ambient ozone in California, the San Joaquin Valley, and elsewhere in the West?

2. What additional observational research is necessary in order to develop more robust models that can be used by air districts to more accurately represent the contribution of TAO to surface concentrations?
The second DISCOVER-AQ campaign occurred in the California’s San Joaquin valley in January-February, 2013.

The focus was on particulate matter pollution.

Final results are not yet available.
A global climatology of stratosphere–troposphere exchange using the ERA-Interim data set from 1979 to 2011

B. Škerlak, M. Sprenger, and H. Wernli

ETH Zurich, IAC, Universitätstrasse 16, 8092 Zürich, Switzerland

Fig. 17. Seasonally averaged deep STT ozone flux into the PBL for 1979–2011. For this calculation, the ozone concentration is kept constant along the trajectories after crossing the tropopause. The orange contours indicate areas where the ozone flux across the tropopause due to deep STT is higher than 7 kg km$^{-2}$ month$^{-1}$.
On the life cycle of a stratospheric intrusion and its dispersion into polluted warm conveyor belts

O. Cooper,1,2 C. Forster,3 D. Parrish,2 E. Dunlea,2,4 G. Hübler,1,2 F. Fehsenfeld,2 J. Holloway,1,2 S. Oltmans,5 B. Johnson,5 A. Wimmers,6,7 and L. Horowitz8

NOAA P3 flight off the California coast, May 11, 2002
Observations from the TOPAZ airborne ozone lidar aboard the NOAA Twin Otter on May 29.

Shown is a north-south transect 10 km west of Joshua Tree National Park. The solid black curve shows the May 29 ozonesonde profile.
Continental U.S. distributions of median stratospheric contribution to MDA8 surface ozone from April–June 2010 as estimated by the NOAA GFDL AM3 model.
Observations of ozone transport from the free troposphere to the Los Angeles basin

J. A. Neuman,1,2 M. Trainer,2 K. C. Aikin,1,2 W. M. Angevine,1,2 J. Brioude,1,2 S. S. Brown,2 J. A. de Gouw,1,2 W. P. Dube,1,2 J. H. Flynn,3 M. Graus,1,2 J. S. Holloway,1,2 B. L. Lefer,3 P. Nedelec,2 J. B. Nowak,1,2 D. D. Parrish,2 I. B. Pollack,1,2 J. M. Roberts,2 T. B. Ryerson,2 H. Smit,5 V. Thouret,4 and N. L. Wagner1,2

Table 1. Free Tropospheric Air Mass (FT Air Mass) Chemical Characteristics in the Four Air Mass Types Determined in Section 3.2

<table>
<thead>
<tr>
<th>FT Air Mass</th>
<th>Dates (2010)</th>
<th>Water Vapor (g/kg)</th>
<th>CO (ppbv)</th>
<th>HNO₃ (ppbv)</th>
<th>PAN (ppbv)</th>
<th>Ozone (ppbv)</th>
<th>Fraction of Observations (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT</td>
<td>4 May, 8 May</td>
<td>0.8 ± 0.4</td>
<td>108 ± 6</td>
<td>0.4 ± 0.1</td>
<td>0.11 ± 0.04</td>
<td>71 ± 8</td>
<td>38</td>
</tr>
<tr>
<td>Long range transport</td>
<td>8 May, 20 June</td>
<td>1.0 ± 0.4</td>
<td>136 ± 10</td>
<td>0.2 ± 0.2</td>
<td>0.21 ± 0.09</td>
<td>69 ± 6</td>
<td>16</td>
</tr>
<tr>
<td>Aged regional emissions</td>
<td>14, 16, 19 May</td>
<td>3.0 ± 0.6</td>
<td>134 ± 7</td>
<td>0.9 ± 0.5</td>
<td>0.27 ± 0.13</td>
<td>65 ± 4</td>
<td>34</td>
</tr>
<tr>
<td>Marine</td>
<td>19 May</td>
<td>3.4 ± 1</td>
<td>106 ± 10</td>
<td>0.8 ± 0.4</td>
<td>0.15 ± 0.08</td>
<td>53 ± 10</td>
<td>11</td>
</tr>
</tbody>
</table>

For each air mass classification, the dates and average water vapor, CO, HNO₃, PAN, ozone, and fraction of observations measured in vertical profiles between 1.8–3.5 km over the LA basin are shown.
Tracer correlations from aircraft measurements can be used to identify times when TAO reaches the surface.

During CALNEX free tropospheric ozone was identified in:
- LA Basin surface (required a surface site)
- San Joaquin Valley planetary boundary layer
- High desert planetary boundary layer

Challenges to this approach:
- Aircraft observations are expensive and require several chemical tracers
- Instrumented ground sites are also required
- Still difficult to distinguish between TAO and locally produced ozone
Tropospheric ozone monitoring in western North America

Routine in situ ozone measurements from Earth’s surface to the tropopause are made at only 5 ozonesonde sites in western North America.

Only Trinidad Head on the west coast is representative of baseline ozone.

baseline ozone - ozone measured at a location with no recent influence from local pollution sources [WMO GAW definition].

Science Questions:

1) Is Trinidad Head representative of baseline ozone at other coastal sites?

2) What are the anthropogenic NOx emission sources associated with baseline ozone?

3) Once baseline ozone comes ashore, where does it go?
IONS ozonesonde networks
(Intercontinental Chemical Transport Experiment Ozonesonde Network Study)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Season</th>
<th>Location</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>IONS - 2004</td>
<td>Summer</td>
<td>eastern N. America</td>
<td>A. M. Thompson et al., JGR 2007</td>
</tr>
<tr>
<td>IONS - 2006</td>
<td>Spring</td>
<td>Central N. America</td>
<td>A. M. Thompson et al, ACP 2008</td>
</tr>
<tr>
<td>IONS - 2006</td>
<td>Summer</td>
<td>Central N. America</td>
<td>O. R. Cooper et al., JGR 2007</td>
</tr>
<tr>
<td>ARCIONS - 2008</td>
<td>Spring/Summer</td>
<td>northern N. America</td>
<td>S. J. Oltmans et al., Atmos Environ. 2010</td>
</tr>
<tr>
<td>IONS - 2010</td>
<td>Late spring</td>
<td>western N. America</td>
<td></td>
</tr>
</tbody>
</table>
California’s coastal topography affects ozone transport:

Coastal mountains impede the transport of marine boundary layer air into California at Trinidad Head and Pt. Sur [Parrish et al., 2010].

Relatively low topography allows air at Pt. Reyes to enter the Central Valley in the vicinity of The Carquinez Strait [Bao et al., 2008].


IONS-2010 ozonesonde network

Near daily ozonesondes were launched from 7 sites between May 10 - June 19, 2010.

A total of 230 sondes were launched, the most in any western North America field campaign.

Funding, operations and support provided by:

- NOAA ESRL Health of the Atmosphere Program
- NASA Tropospheric Chemistry Program
- U. S. Navy
- Environment Canada
- NOAA National Weather Service
- National Park Service
- California State Parks
- Naval Postgraduate School (Monterey)
- Federal Aviation Administration
Percent difference in total mass of ozone per km (0-8 km), for southern sites compared to Trinidad Head.
Percent difference in total mass of ozone per km (0-2 km), for southern sites compared to Trinidad Head.
Baseline ozone determined by removing all measurements with a 5-day North America NO\textsubscript{x} tracer $> 350$ pptv.

Decrease in baseline ozone is calculated in units of: mPa O\textsubscript{3} km\textsuperscript{-1}.
Percent difference in total mass of ozone per km (0-5 km), for inland sites in comparison to coastal sites at similar latitude.
Percent difference in total mass of ozone per km (0-2.5 km), for inland sites in comparison to coastal sites at similar latitude.
Percent difference in total mass of ozone in the lowest km of the atmosphere, for inland sites in comparison to coastal sites at similar latitude.
Percent difference in total mass of ozone per km (0-3.4 km a.s.l.) for:
LA Basin and Joshua Tree compared to San Nicolas Island.
Percent difference in total mass of ozone per km (0-1.0 km a.g.l.) for:
LA Basin and Joshua Tree compared to San Nicolas Island.
Impact of baseline ozone on the surface of the United States
Ozone Network Design

- Goal of providing observations to evaluate the models that estimate TAO at the surface

- What observations are currently available?

- What additional observations are required for California, while still being realistic in terms of funding?
Locations of current EPA ozone monitors, mainly urban
Western North America: Routine $O_3$ measurements

21 Rural surface ozone sites:
- EPA CASTNET
- National Park Service,
  Trinidad Head (NOAA),
- Mt. Bachelor (D. Jaffe, U Washington)
- Chews Ridge (Ian Faloona, UC)
Western North America: Routine meteorological measurements

Hourly surface observations at dozens of sites

18 rawinsonde sites, launched twice daily at 4:00 and 16:00 PST

Ozone profiles at:
- Trinidad Head (NOAA) weekly ozonesondes
- Table Mountain NASA JPL lidar, 3 km - stratosphere
One of TOLNet’s goals:

Advance our understanding of processes controlling regional background atmospheric composition (including STE and long range transport) and their effect on surface air quality to prepare for the GEO-CAPE era.
NOAA Earth System Research Lab Aircraft Program
Greenhouse gases plus ozone up to 8 km
Scientific Aviation
Dr. Stephen Conley
CO2, CH4, and ozone among other trace gases up to 8 km

Contact Scientific Aviation
Email: sconley@scientificaviation.com
Main: (916) 217-1107
1608 Old Hart Ranch Road
Roseville, CA 95661
IAGOS equipment is designed for installation in the avionics compartment of Airbus A330 aircraft.

Species that can be measured include:

- ozone
- carbon dioxide
- methane
- particulate matter
- carbon monoxide
- nitrogen oxides
- total reactive nitrogen
- water vapor
- cloud droplet backscatter

Flight tracks and flight frequency during 2009 of all A330 aircraft based in the United States. Figure produced by S. D. Jacob, FAA.
California GDP in 2012: 1,959 billion USD
Taiwan GDP in 2012: 465 billion USD

An example of IAGOS CO profiles above Taipei, Taiwan
Figure by Kuo-Ying Wang, National Central University, Taiwan
Ozone Network Design

Surface monitoring:
Take advantage of existing Trinidad Head MBL and Chews Ridge mountain top ozone monitors.

Add MBL ozone monitors to Pt Reyes and Vandenburg AFB.

Add a mountain top site west of Redding.

Daily Vertical Profiles:
Highest priority is an ozone lidar at Pt Reyes or Bodega Bay.

Lidars at Trinidad Head and Vandenburg AFB are also needed.

Launch ozonesondes on cloudy days.
Impact of baseline ozone on the surface of the United States
Impact of baseline ozone on the surface of the United States

- Trinidad Head
- Pt. Reyes
- Pt. Sur
- San Nicolas Is. 

Measured ozone (blue), ppbv
and sample size (white)

O³ transported to surface (g/cell)
averaged over all forward plumes

avg O³ mass (g) from each level transported to surface
based on maximum daily value over 5 days
Passive 20-day anthropogenic NOx tracers above the individual coastal sites.

Retroplume release altitude = 0 - 8 km

Column: T. Head, n=1384
Footprint: T. Head, n=1384

Column: Pt. Reyes, n=1270
Footprint: Pt. Reyes, n=1270

Column: Pt. Sur, n=1451
Footprint: Pt. Sur, n=1451

Column: San Nic. Is., n=912
Footprint: San Nic. Is., n=912

Ozone (ppbv): blue
RH (%): green
% from strat.: yellow
Sample size: white
Total: black
N. America: yellow
China: red
Jap/Kor: blue
SE Asia: green
India: cyan
Europe: magenta
NH shipping: magenta