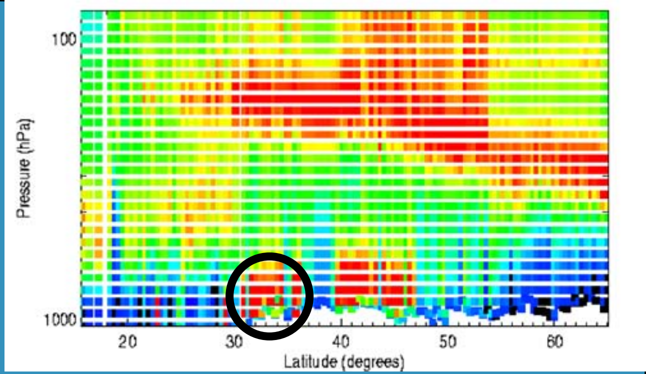
U.S. – Mexico – Border AMI Project



TES Vertical O_3 0 40 80 >120 ppb

QuickTime™ and a Graphics decompressor are needed to see this picture.

OMI NO_2 in the Southwest

US EPA: *Vance Fong, Debbie Lowe, Jan Baxter, David Fege* (Reg 9).
Mark Sather, William Luthans (Reg 6)
Harold Zenick, David Williams (ORD)

NASA: <u>*Robert Chatfield* (Ames), *Greg Osterman* (JPL)</u>

CDC: *Raquel Sabogal*

Mexico: Beátriz Cardenas (SEMARNAT: Environ./Natural Res.)

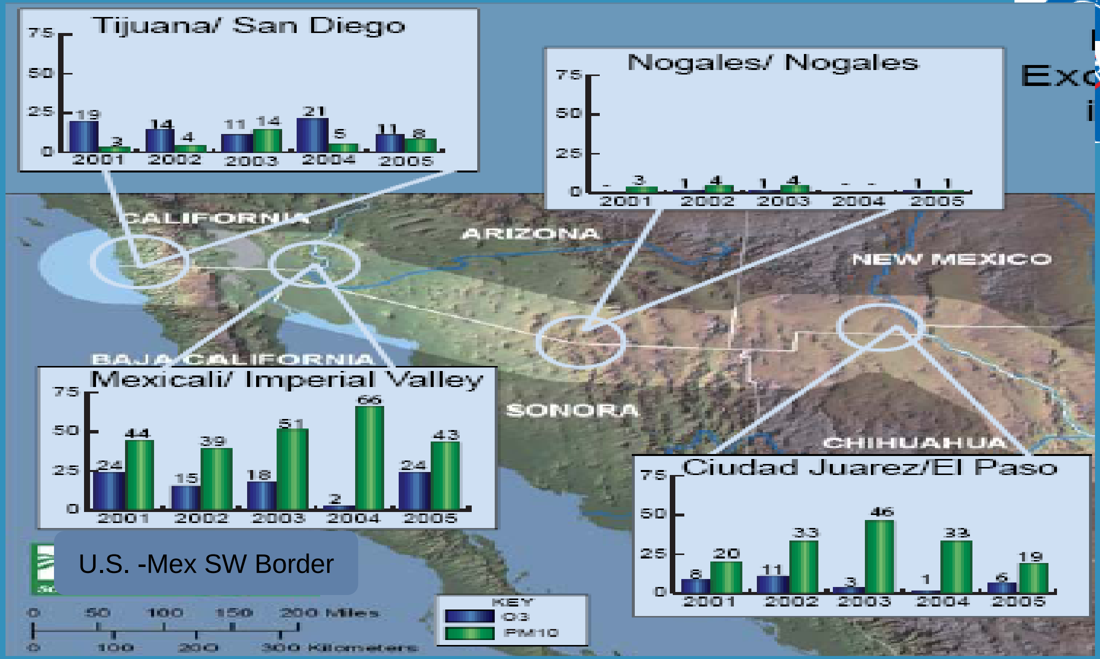
SCERP: *Rick Van Schoick* (San Diego SU)
H. Joe Fernando, Nancy Selover, Chune Shi, (ASU)

U.California, Berkeley: *Edmund Seto*

Pan-American Health Organization: *Sally Edwards*

+ Bonus report: <u>highlights</u> of good stuff to come for Air Quality

Motivating conceptions



• Recently available lower tropospheric ozone and precursor data from satellite sensors,

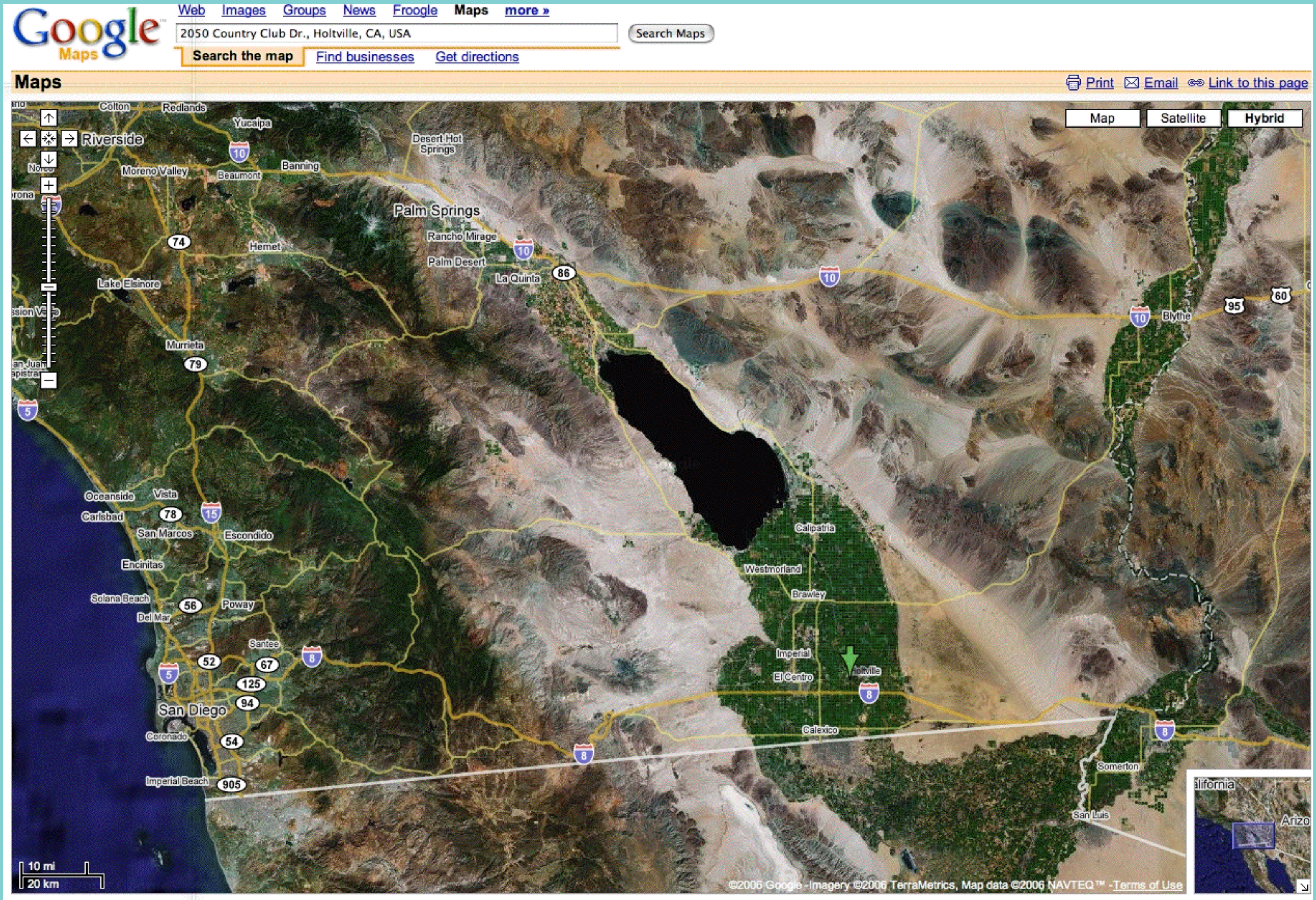
….when combined with existing surface monitoring data and sporadically available ozone sonde flights

….can improves our understanding of regional ozone pollution, its severity, transport, and episodes for the Border Region.

• The improved knowledge of ozone can … assist state and local officials in addressing asthma and other ozone-related health issues for impacted communities.

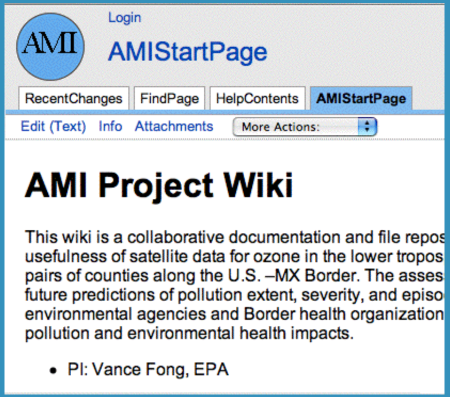
Do Air Basins of California and Border Areas Communicate?

…Sometimes yes, sometimes no!



2005–2006 and August Study

- The project moved to study 2006 and particularly August, 2006
  - –August 2006 allowed coordination and support from IONS, TexAQS modeling (for context)
  - –There have been polluted August periods
  - –We (Chatfield) arranged for ozonesonde launches to understand the inland areas: Dennis Fitz, UC Riverside. Little prior info: ground <=> sonde <=> satellite ozone
- August 2006 was not very polluted:
  - –So we studied one modestly polluted period, August 9-11
  - –And we broadened to exceedance days



OMI-MLS Ozone/Sonde/Surface Station Comparison

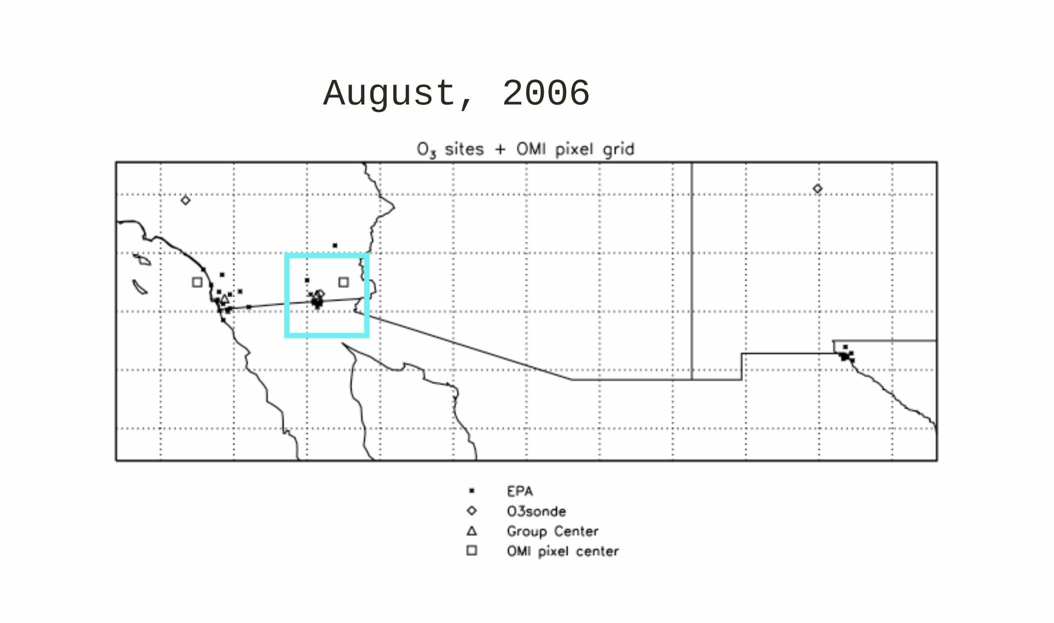
-------	OMI Imperial Valley	group avg	sta 002	sta 003	sta 004	Holtville 1050-850	Holtville 800-500	Holtville tropo
OMI ImperialValley	*1*	-0.27	-0.01	-0.24	-0.18	0	0.77	0.92
group avg		*1*	0.31	0.7	0.62	0	-0.29	0
sta 002			*1*	-0.23	0.3	0.65	-0.13	0
sta 003				*1*	0.54	0	-0.21	-0.21
sta 004					*1*	0.24	-0.03	-0.09
Holtville 1050-850						*1*	0.27	0
Holtville 800-500							*1*	0.9
Holtville tropo								*1*

Correlation Coefficient

OMI correlates remarkably well with sonde totals

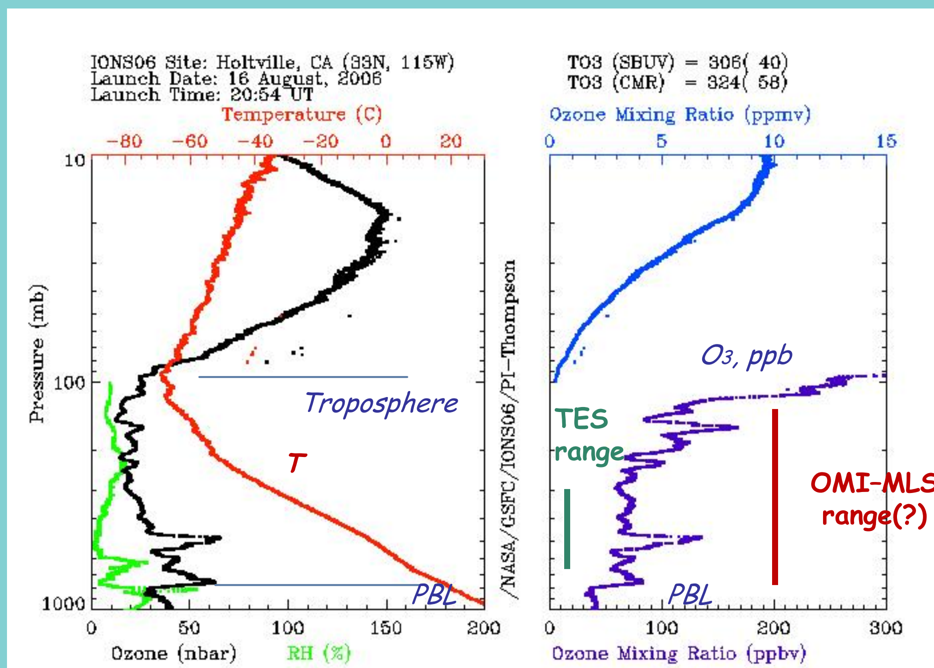
Stations do not correlate with OMI or sondes,

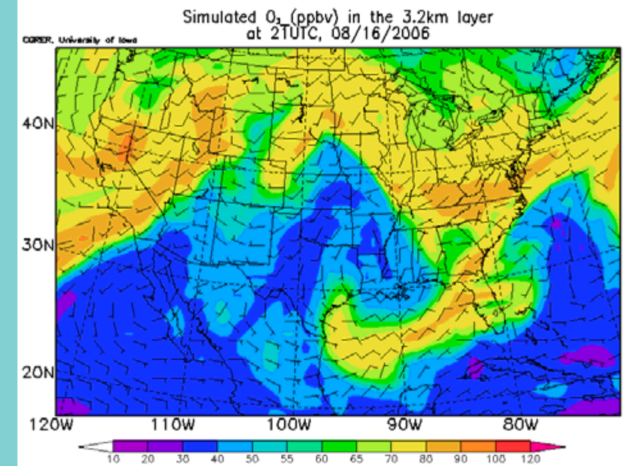
… don't cor-relate well with each other !

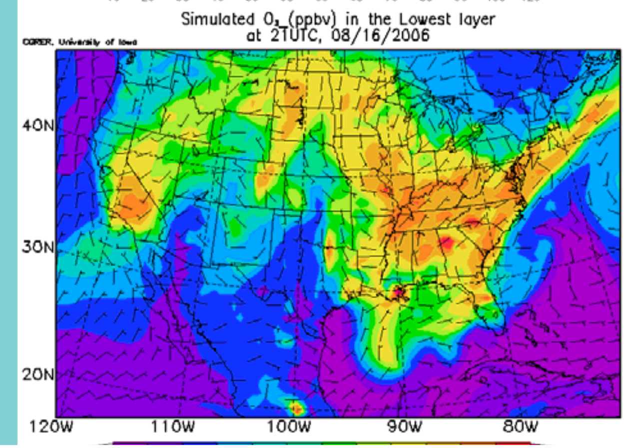


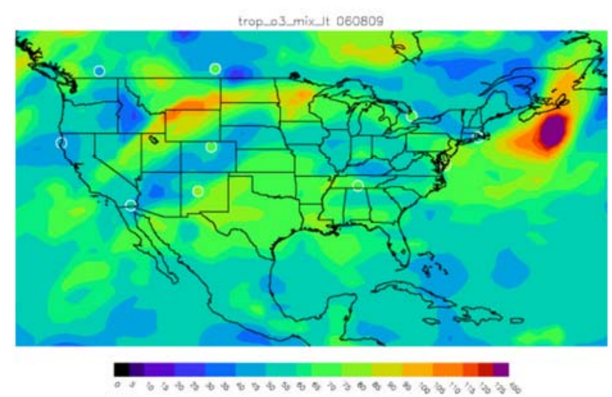
Conclusions:
(1) Limit expectations of correlations
(2) reconsider ozone sensor locations!
…just which represent sensitive populations
(3) Q.A. for ozone is different

- *Layering of ozone in PBL and frequent elevated layers in the Southwest … zooming down the east side of the Pacific Anticyclone*
- *This often confound lower-tropospheric interpretations*



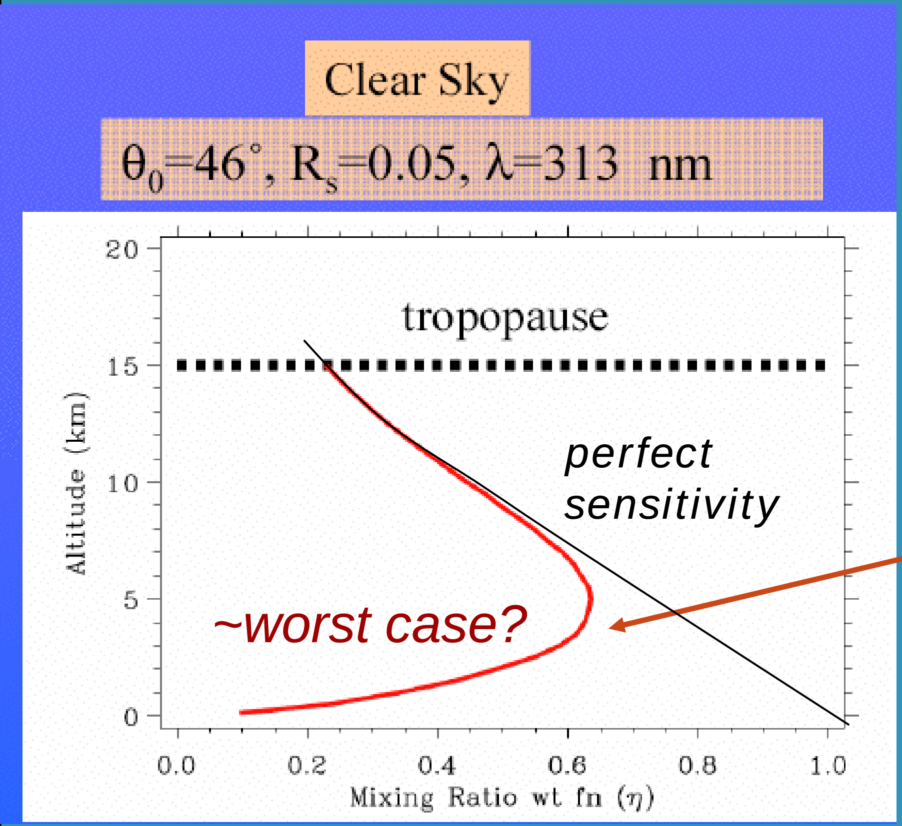






Holtville Launches UC Riverside / Dennis Fitz & James Bristow

M. Schoeberl [2007] early OMI-MLS to Tropopause map



- *Senstivity from — P.K. Bhartia, GSFC, progress report presentation, November, 2005*

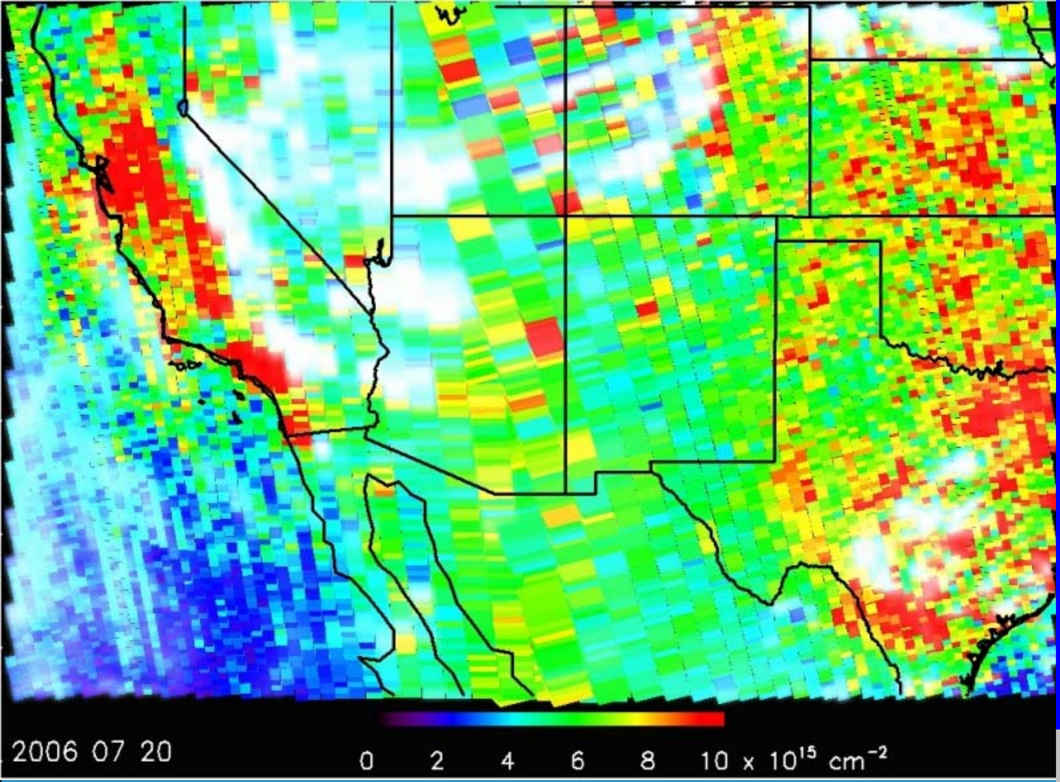
Why does OMI have ~ no correlation to sfc O_3?

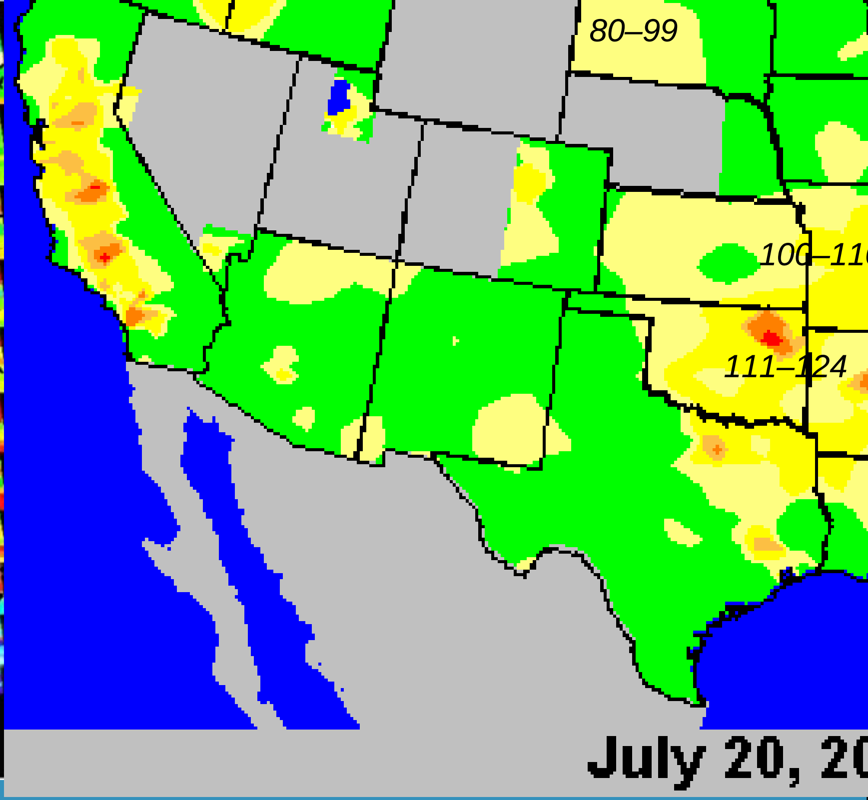
(1)Tropospheric ozone sensitivity is thought to be poor in lower troposphere;

likely greater at SW border latitudes: high surface albedo, less slant path

(2) Interior Intermountain deserts/high plains have deeper mixing to ~2–3 km above surface. Not Imperial Valley.

(3) West Coast atmospheric circulation may bring down "exotic" layers (Asia, stratosphere, …) on E side of high in a way not so frequent in SE USA anticyclones.





NO_2 column on July 20, 2006.
This was the period of record heat and record ozone throughout much of Central California.
The Border region east of San Diego was experiencing winds from the Pacific and was spared both heat and ozone; instead there were "Southwest Monsoon" rains.

- *Substantial similarities between the NO2 distributions and Ozone distributions for this day.*
- *This may be expected for strong stagnation conditions where NO_2 accumulates and produces ozone in a region near the NO_2 source. Ozone distributions are often more widespread.*

OMI NO_2 is the most reliable indicator of air basins where one may expect similar levels of ozone, although NO_2 is not quantitative for ozone

=> Movie shows “stagnation” basins and broader transport days (less distinctly)

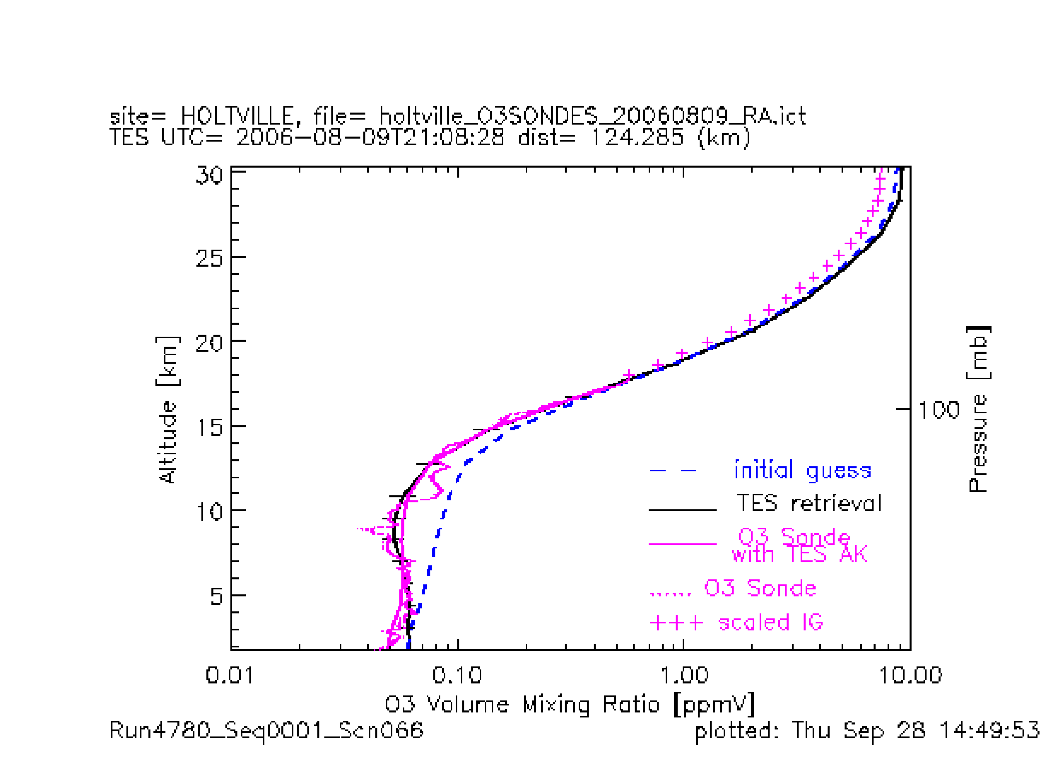
QuickTime™ and a
Graphics decompressor
are needed to see this picture.

Update on TES data for the EPA AMI Project

Greg Osterman
Jet Propulsion Laboratory/
California Institute of Technology

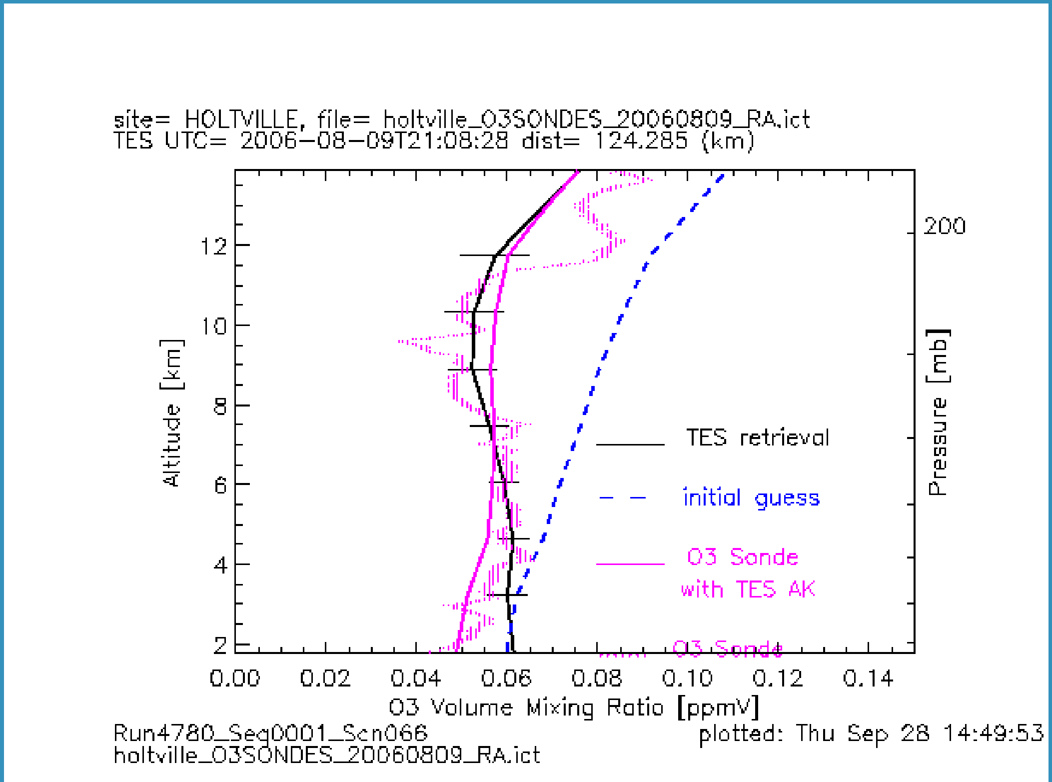
January 12, 2006

Holtville – August 9, 2006



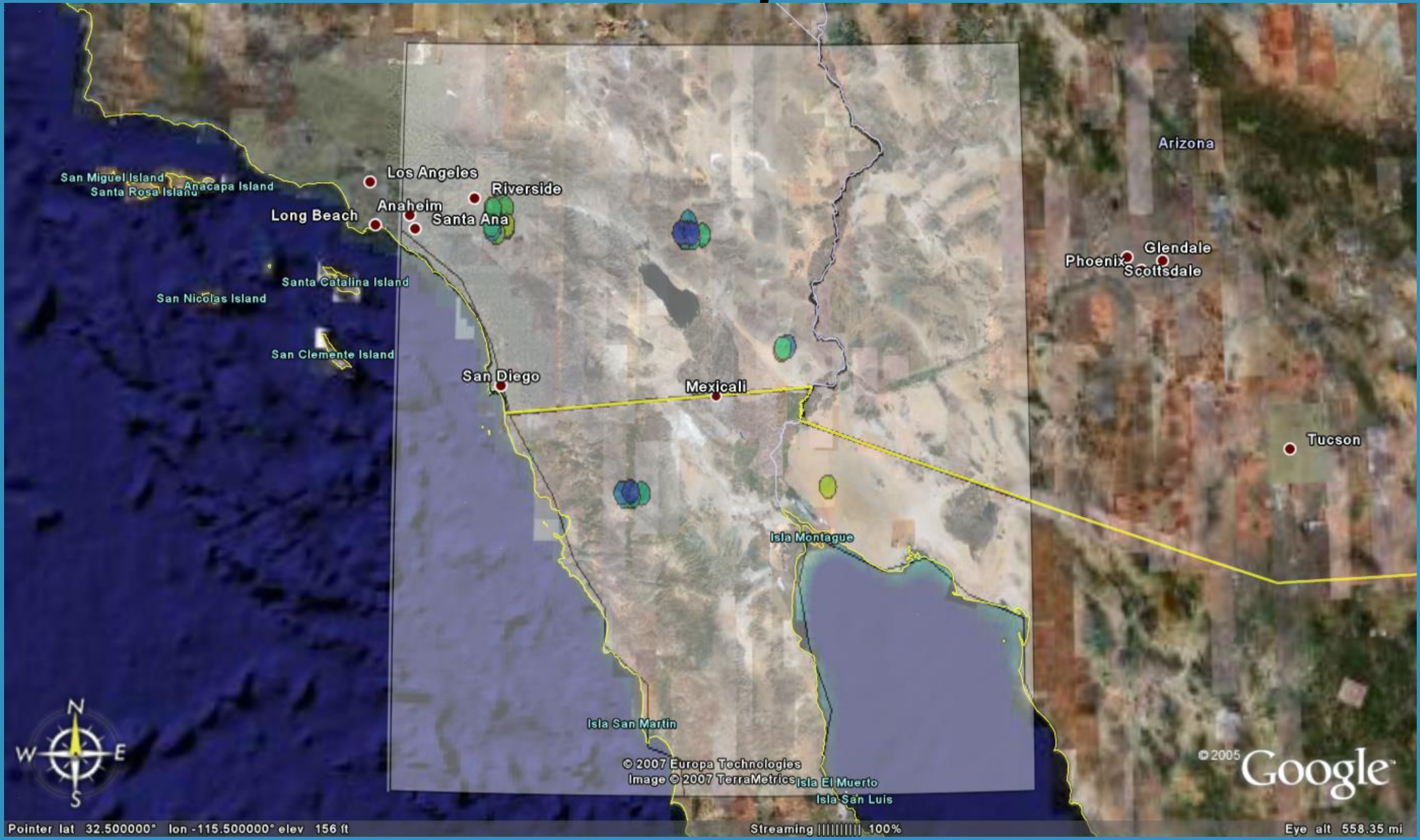
- Compare to both the sonde data and the sonde data convolved with the TES averaging kernel.
- Good comparison in mid-troposphere up through lower stratosphere
- Signifcant high bias in TES data compared to sonde below 4 km

Holtville – August 9, 2006

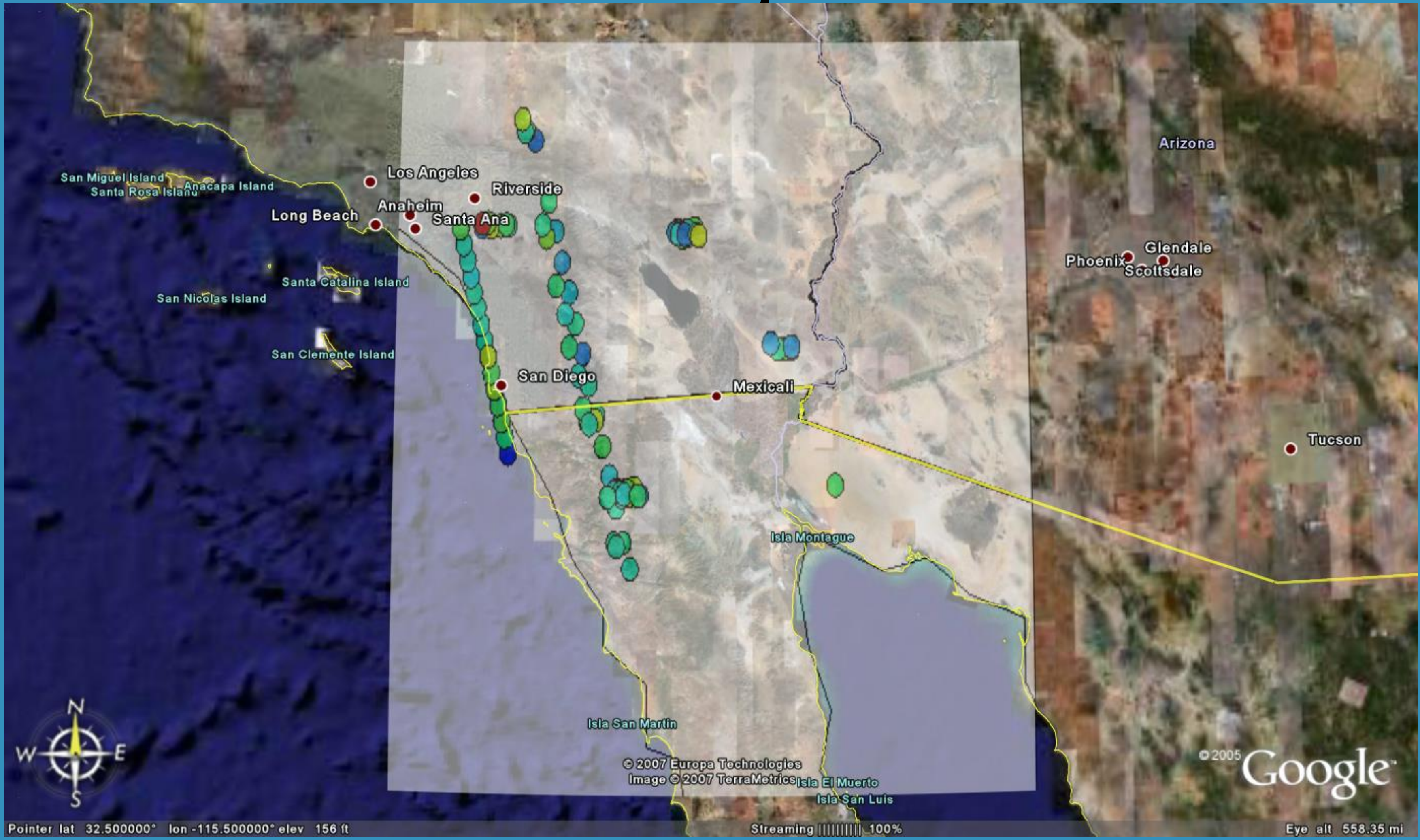


- TES sees ~10-12 ppb more ozone 2-4 km
- TES data has been shown to have a high bias when compared to sondes in most of the troposphere.
- TES ozone has been compared to ozonesondes launched all around the world
- Lidar comparisons to TES data give results consistent with the ozonesonde data.

2005 TES Data near San Diego

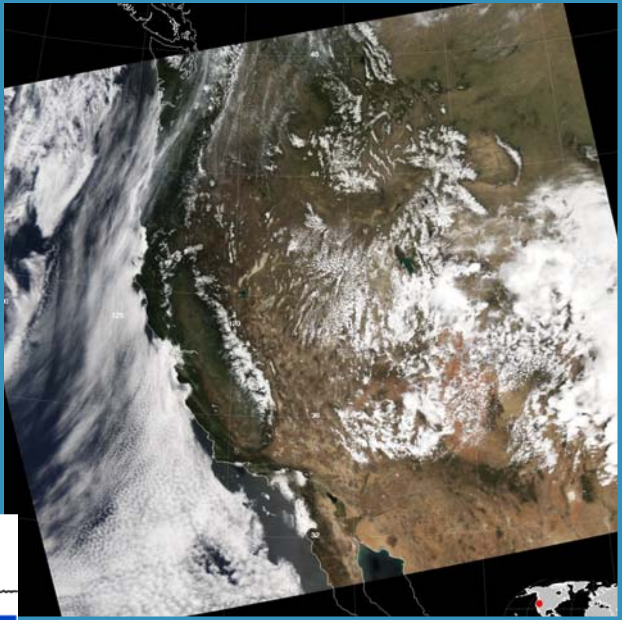


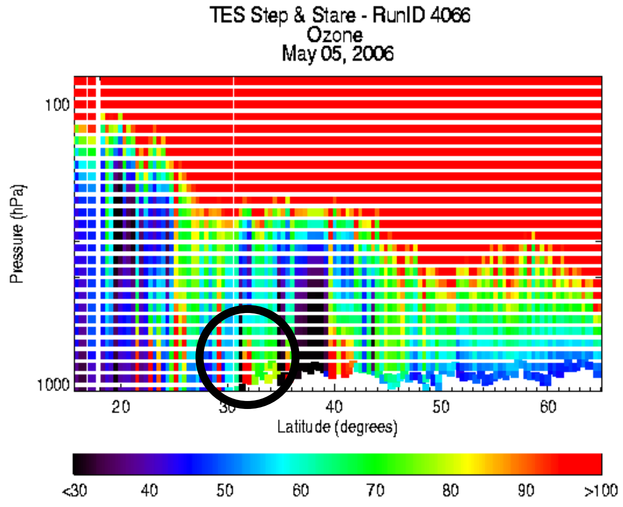
2006 TES Data near San Diego

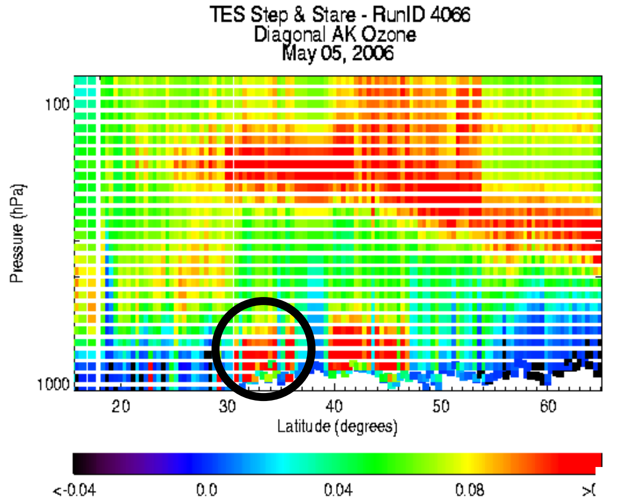


TES Data - May 5, 2006

- TES special observation (Step & Stare)
- Good sensitivity in the lower troposphere nearest Mexicali
- Clear skies near border





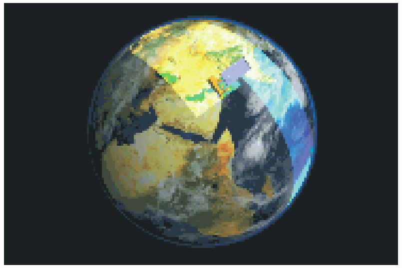


Bonus: Other ways NASA research can help

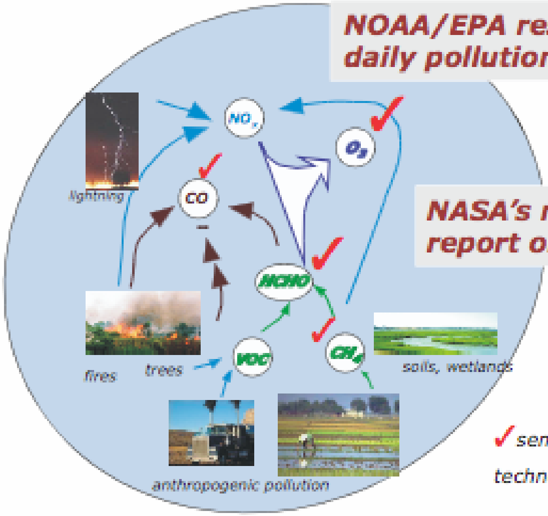
- Better Space Observations: small, inexpensive instruments can see to the PBL and reveal smog production in the 3.5 μm IR—Launch with small-sats, comsat (geostationary)
- Tropospheric ozone estimates can come from such small instruments (ask me).
- Better Surface Observations: local production of ozone and local VOC/NO_x sensitivity can be measured at a well-relocated, reinstrumented sites…a NASA suborbital data result

Robust Infrared Mapping for Tropospheric Ozone Prediction

R. Chatfield / Ames, J. Kumer, A.Roche, J. Mergenthaler / L-M ATC Palo Alto,
L. Strowe / UM BC, … K. Chance / Harvard-Smithsonian Astrophysics



NOAA/EPA responsiblity for daily pollution forecasts



NASA's mandate to report on Earth's ozone

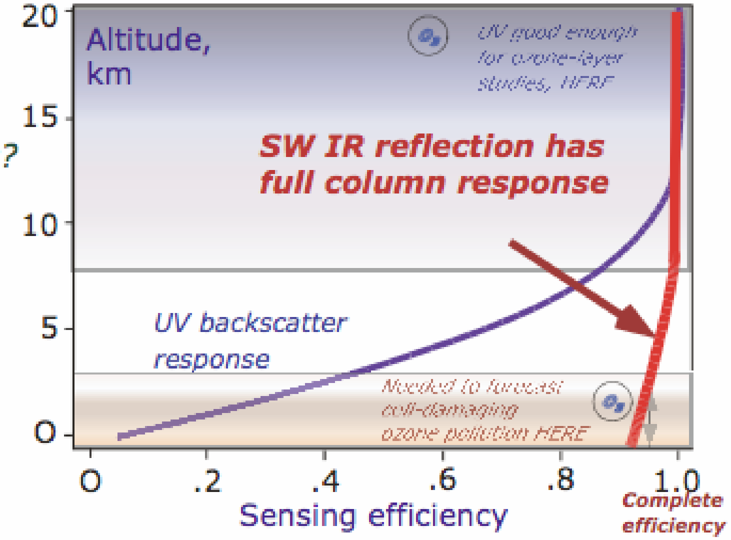
✓ sensed by this technology !

<u>**Tropospheric Infrared Mapping Spectrometry**</u>

- ***Elegant, small, robust, cheap: Grating Mapping Spectrometers have ONE MOVING PART, vis: Cal On/Off … ~20 kg + radiative cooling, etc.***
- *Daily, global maps to highlight regional and long-distance pollution threats.*

- *UNEXPLORED reflective IR wavelengths usable with new detector technology: complement or supplant limited UV techniques?*

TIMS adds tropospheric information allowing 0–2 km O3 to ~15% per area



A Basic Demonstration Sensor Set: O_3 and HCHO

Spectral Region	Approx. λ	Frequency resolution	Nadir ELF [1]	Primary Measurement (potential measurement)	Consequent Additional Benefits
SWIR	3.56 μm	< 0.35 cm^{-1}	3.2 km	HCHO, CH_4, N_2O, and maybe some O_3 info	HCHO summarizes pollution Volatile Organic Carbon compound smog-activity; high precision column info and some vertical info for HCHO, CH_4 & N_2O
SWIR	3.3 μm	< 0.35 cm^{-1}	3.2 km	O_3, CH_4 Good reflectivity	Adding 2nd slit gives more O_3 sensitivity

1- ELF: Elemental (smallest sampled) footprint
2- BL: Planetary Boundary Layer

We should have rising expectations … but need NOAA, EPA <u>continuing</u> support

POGO-FAN:
Remarkable Empirical Indicators for the Local Chemical Production of Smog-Ozone and NOx-Sensitivity of Air Parcels

QuickTime™ and a
GIF decompressor
are needed to see this picture.

•Chatfield, R B

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•NASA Ames Research Center, Earth Science MS 245-5, Moffett Field, CA 94035 United States

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•Shetter, R E shetter@ucar.edu
•Singh, H B Hanwant.B.Singh@nasa.gov

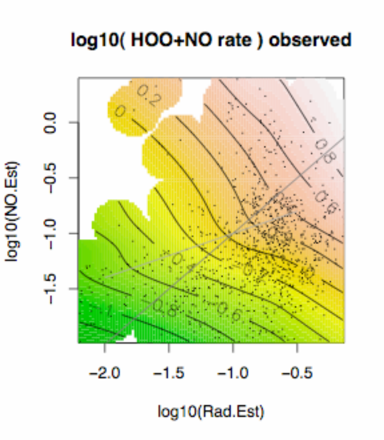
QuickTime™ and a
GIF decompressor
are needed to see this picture.

6 **there**

Is there really a subtle near-linearity to smog???

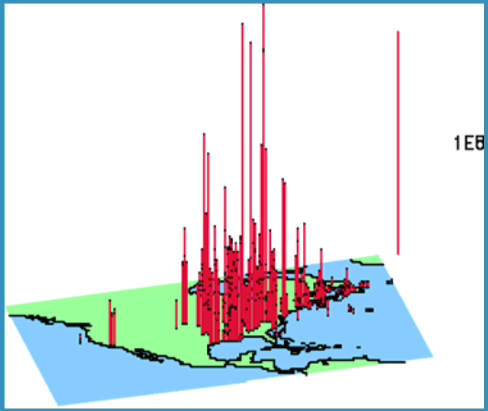
1996 regional smog

Production of
Ozone by
Gauging of
Organic Oxidation:
-
Formaldehyde
And (**A**ctinic Flux and)
Nitric Oxide



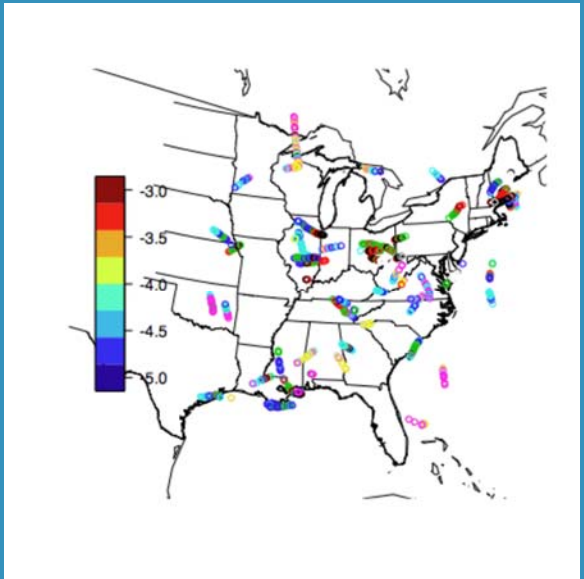
Production of Ozone in the PBL

Production of
Ozone by
Gauging of
Organic Oxidation:
-
Formaldehyde
And (**A**ctinic Flux and)
Nitric Oxide



Wide range of $P(O_3)$ during INTEX-NA (molecular units)

INTEX-NA in July-August 2004 provided a very broad sweep of somewhat polluted air in Eastern North America
… ideal for broad tests
But we still need surface, all-day-long tests

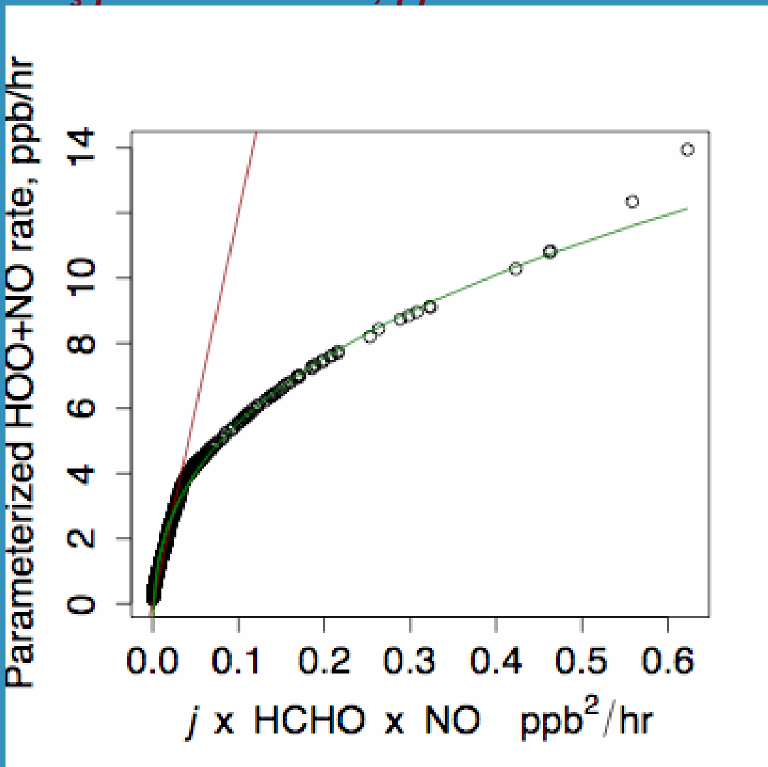


- ***Wide Range of "Organic Activity" to NOx ratio** Color scale refers to log10 of the "formaldehyde activity" divided by the NOx concentration, in ppt units. Formaldehyde activity is taken to be the formaldehyde concentration times its photolysis rate (s^{-1}) to radicals*

DC-8 PBL samples,
Exploit Brune (PSU) HOO
Fried (NCAR) HCHO
Shetter (NCAR) j's
Crawford/Olson (LaRC) point model

$P^o(O_3)$ "principal"

O_3 production rate, ppb hr^{-1}

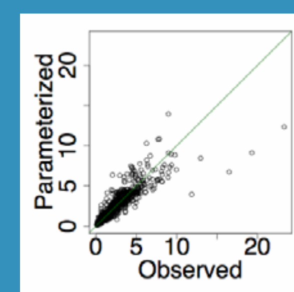


POGO-1

A key or **"index variable"** that is not ozone production but contains "all" necessary information

$$\alpha = j_{rad} \cdot HCHO \cdot NO$$

a ***tracer*** of HOO radical production rates, ***related to*** HOO concentration.

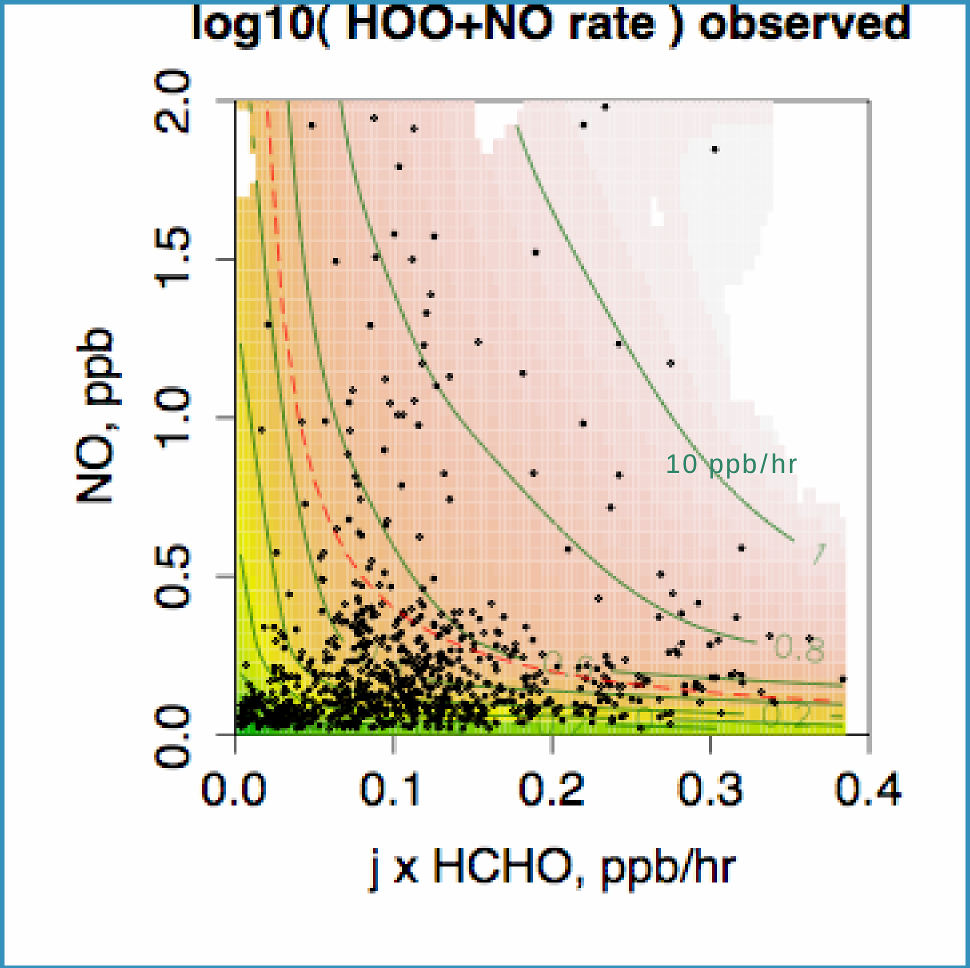


j_{rad} *photolysis of HCHO to form radicals. A fairly "hard-UV" rate like that taking O_3 to $O(^1D)$*

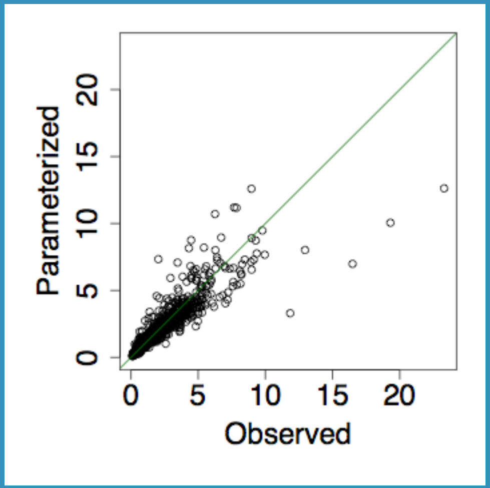
guide lines show approximations...

$P^o(O_3)$ = 80α at lowest NO and radical production

$P^o(O_3)$ prop. to $\alpha^{0.37}$ in HO_2+HO_2 (etc) falloff region

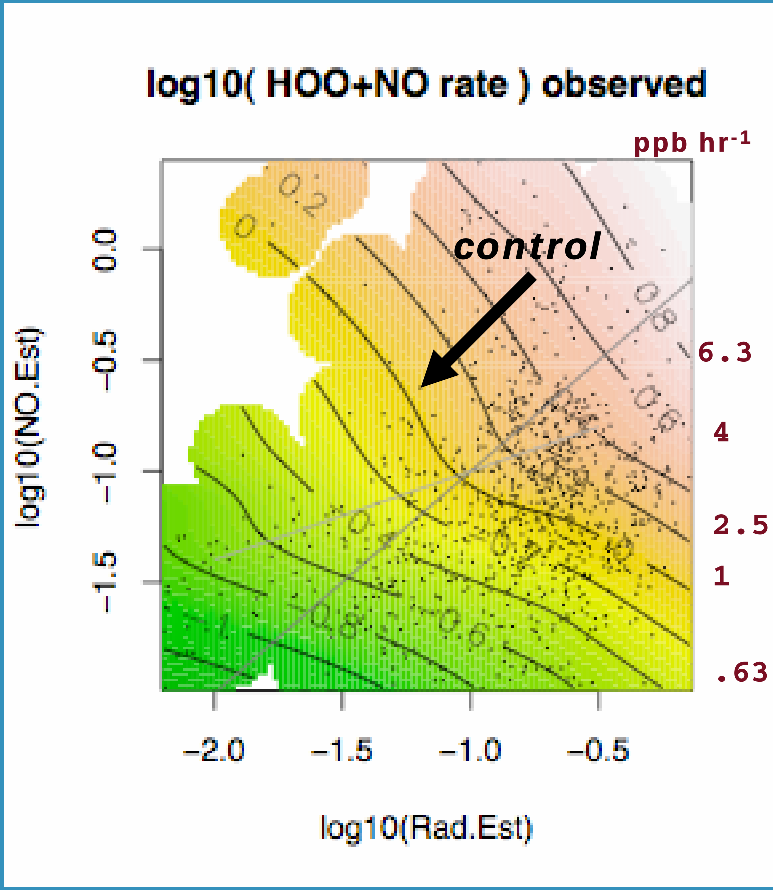


POGO-2



This observations suggest a nearly simple (x y = constant) relationship, consistent with POGO-1

POGO-2 description of control strategy is extremely simple:



isopleths: x y = constant => Δy / Δx = – x / y

implement what you can to lower NO and HCHO (via VOC emissions)

so as to achieve steepest descent technically possible

Where are VOC-limited

and NOx-limited regions?

Ans: They are present, but are simplified by logs to descriptions of

relative reductions … e.g., NOx (and NO) may amount to many ppb

To-do: *$P^o(O_3)$ should integrate throughout a day at one locale — show how VOC/NOx positions on the plot change during the cycle of daylight*

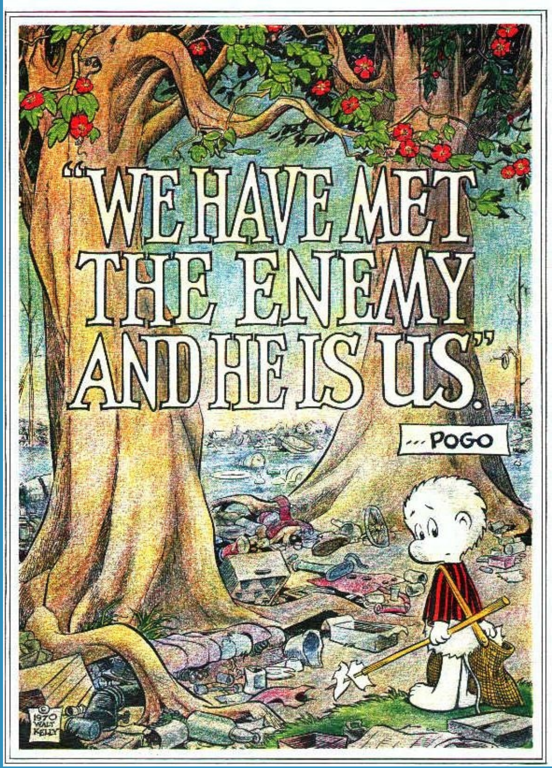
Conclusions

- *OMI- and TES-derived ozone reflected tropospheric ozone well, but did not reflect surface ozone due to*
  - *relatively shallow Imperial Valley mixed layers; sondes told us this.*
  - *Complex ozone variations above the PBL which characterize the east side of the Pacific Anticyclone (ducting from north)?*
- *OMI-based NO_2 maps suggested air basins and showed both stagnation (very local) effects and broader Southwestern pollution flows: best for extending understanding of surface measurements*
- *Surface stations vary sufficiently from each other that we should not ever expect great station correlations or station/human-exposure correlations … better PAM sites?*
- *TES indicated useful N-S vertical patterns but sampling is infrequent.*

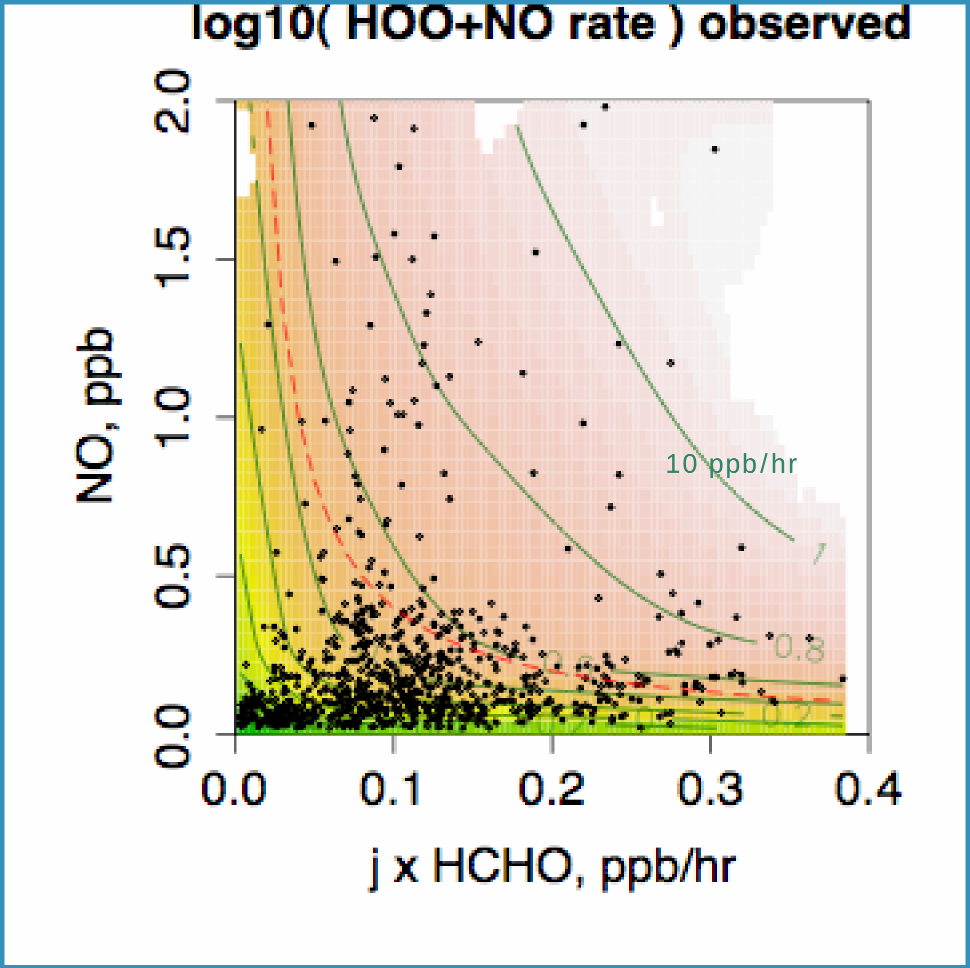
- *Raise expectations! Satellite instruments sensitive to PBL ozone and defining smog ozone production are small, robust, and inexpensive; need continuing interest.*

Better Surface measurements: locations and species

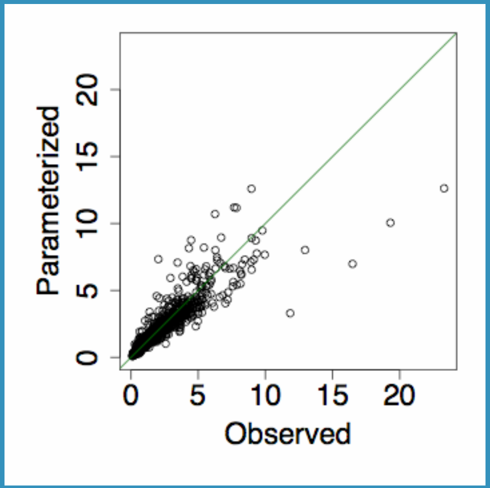
- *A simple formula, a non-linear function of j(HCHO)•HCHO•NO, captures ozone production over ~2 hour periods*
- *A two-dimensional formula, involving j(HCHO)•HCHO and NO and provides a local analog to an EKMA analysis*
- *Relatively simple local measurements of j(HCHO), HCHO, and NO throughout the day suggest locally relevant control strategies <u>limiting further ozone production</u>*



Fin



POGO-2



This observations suggest a nearly simple (x y = constant) relationship, consistent with POGO-1

$P(O_3)$ = (1.57$\pm$0.2) $k_{HO2NO}[HO_2][NO]$ + (0.3+.03)

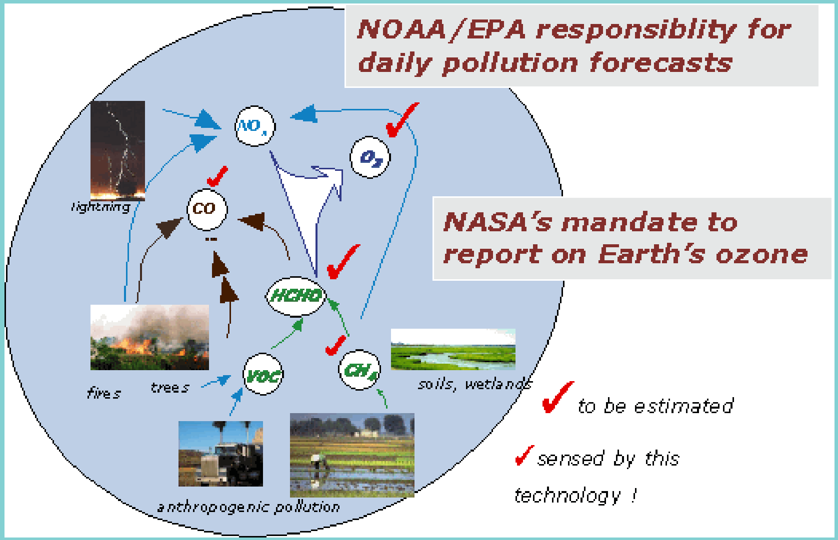
$P(O_3)$ ~ 1.6 $P(O_3)$ *from point-model calculations which can estimate ROO effects*

Robust Infrared Mapping for Tropospheric Ozone

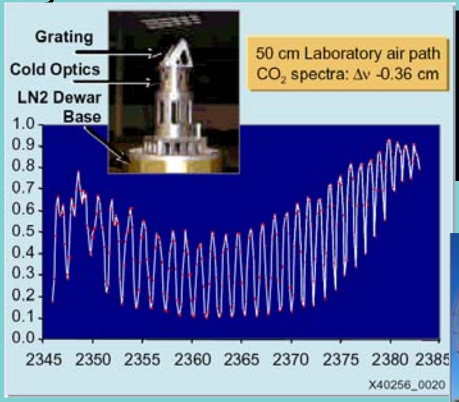
Mission & Objectives

- **Prove and exploit a robust, light SWIR or SWIR/MSIR infrared mapping technology using grating mapping spectrometry (GMS) in LEO**
- **Simplest: One grating, SWIR ~3.55 µm wavelength band**
- **Promising: One SWIR, one MWIR ~4.65 µm**

- **Daily maps of ozone and a major predictor for tomorrow's ozone**
- **Serve pressing national needs for daily "ozone-weather" forecasts**



Systems



TRL 3 (2005) to TRL 5 (2007)
under Instrument Incubator Program Support

Deliverable & Outcomes

Products

- **Unprecedented true ozone column: 2000 km swath, 1–3 km elem pixel**
- **Demonstrates SWIR reflective measurements between clouds**
- **Daily national maps: Smog movements visible and improving NOAA/EPA and NASA forecasts**
- **P(O_3) - ozone production rate visible through formaldehyde (HCHO) measurements.**

Personnel

- **ARC contributions**
  - **Chatfield: Sharp science focus on national needs and benefits**
  - **IT compression technology personnel for large data rate, small satellite**
- **Lock-Mart. Palo Alto Advanced Technology Center contribution**
  - **John Kumer (IIP PI), Aidan Roche, and John Mergnthaler**
  - **Robust, simple technology. *One moving part: calibration!***
  - **Group's history of success and costs with CLAES stratosphere sensor**
- **Partners for downlink, processing**