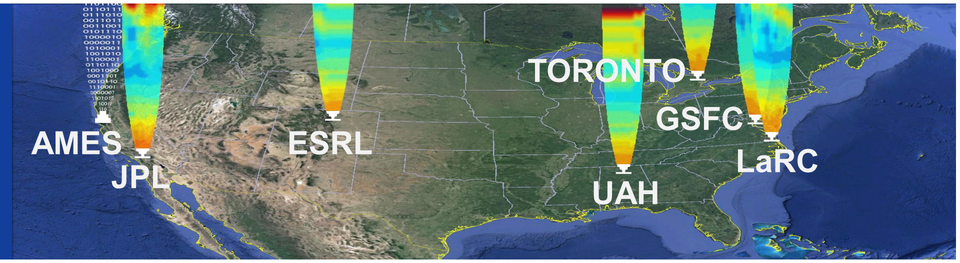
TOLNet

Tropospheric Ozone LIDAR Network



Structure, Capabilities, and Accomplishments of the Tropospheric Ozone Lidar Network, TOLNet, for Background Ozone Determination

ENV-Vision; May 10-11, 2016; Washington D.C.

Jack Kaye[1], Barry Lefer[1], Matthew Johnson[2], Thierry Leblanc[3], Raul J. Alvarez II[4], Guillaume Kirgis[4], Andrew O. Langford[4], Christoph J. Senff[4,5], Steve Brown[4], Bryan Johnson[4], John, F. Burris[6], Shi Kuang[6], Michael J. Newchurch[6] ,Lihua Wang[6], Kevin Strawbridge[7], Thomas J. McGee[8], John T. Sullivan[8], Tim Berkoff[9], Gao Chen[9], Russell J. DeYoung[9], Guillaume Gronoff[9], Brad Pierce[10], Terry Keating[11]

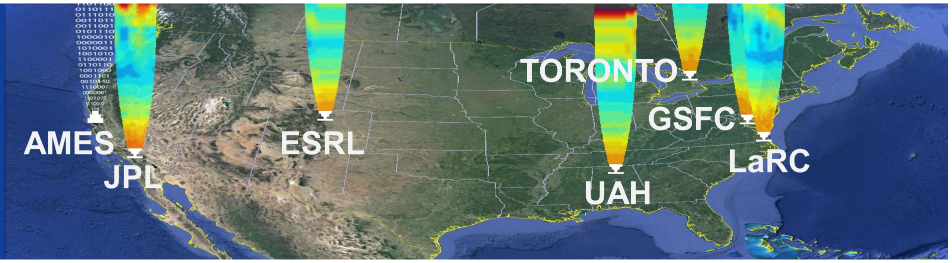
[1]NASA Headquarters, [2]NASA Ames Research Center, [3]NASA Jet Propulsion Laboratory
[4]NOAA Earth System Research Laboratory, [5]University of Colorado at Boulder, [6]University of Alabama in Huntsville, [7]Environment and Climate Change Canada
[8]NASA Goddard Space Flight Center, [9]NASA Langley Research Center, [10]NOAA/NESDIS/STAR, [11]USEPA/OAR

EPA United States Environmental Protection Agency

Environment Canada

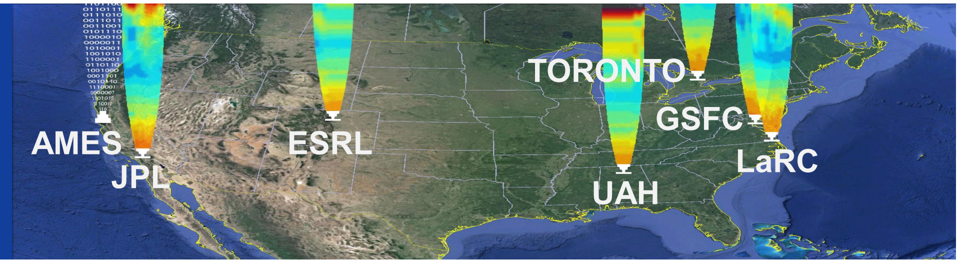
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Overview of Talk



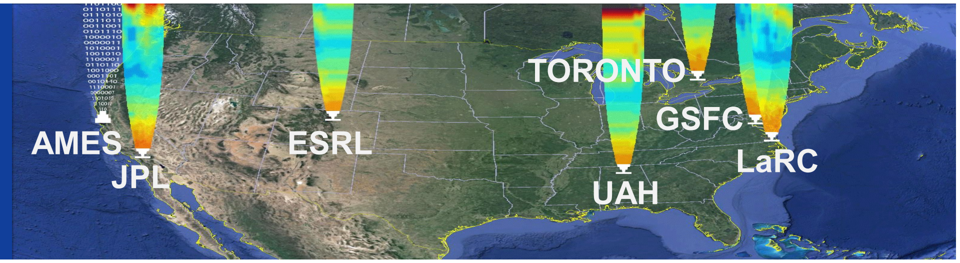
- Global Air Quality, Atmospheric Composition, and Earth System Science
- A Little History …
- The International Constellation
- How TOLNet Complements Space-borne Capability
- High Spatio-temporal-resolution Lidar Observations Address Many Air-quality Problems.
- Putting All the Pieces Together

Global Air Quality, Atmospheric Composition, and Earth System Science

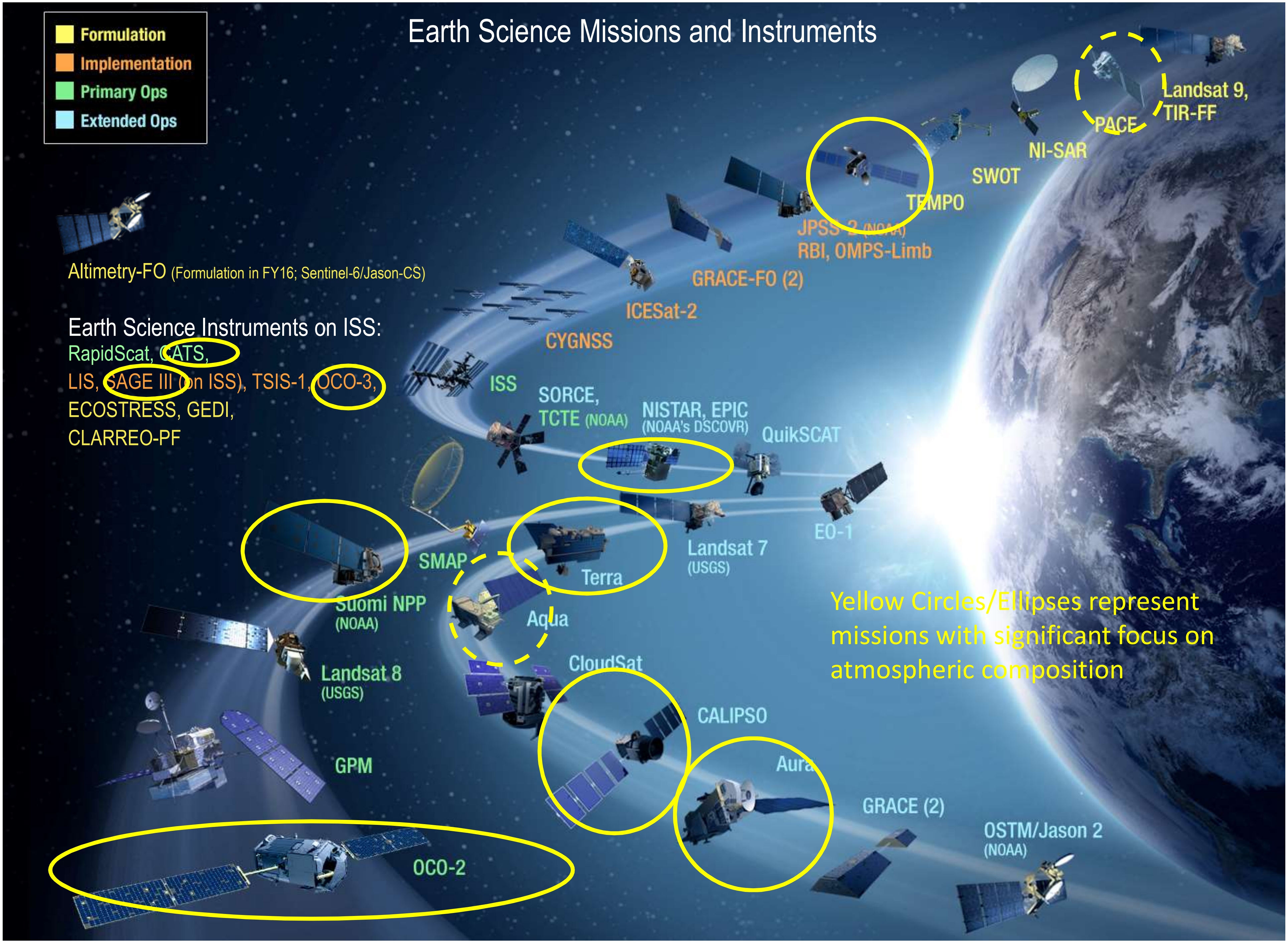


- Overall Goal of NASA's Earth Science Program: To study the Earth as an integrated system ("Earth System Science") and to use the knowledge gained to help improve the quality of life here on Earth
- Atmospheric Composition is one of six major interdisciplinary science focus areas within NASA's Earth Science Research Program
  - Stratospheric Ozone
  - Tropospheric Composition including climate forcing
  - Global Air Quality
- NASA approach uses laboratory studies, satellites, aircraft, surface-based measurements, and models

A Little History …



- NASA has a long history of studying the Earth’s atmosphere, but much of the early satellite work focused on the stratosphere
- Significant early work on global tropospheric chemistry involved airborne measurements (Global Tropospheric Experiment – GTE) to study background atmosphere, interactions with surface, and mechanisms of transport and transformation of trace constituents
- Seminal work on extracting tropospheric ozone information from satellites (Tropospheric Ozone Residual from TOMS/SAGE) broadened NASA program and strengthened linkage between satellite and airborne program
- Additional work by research community added to knowledge of troposphere by extracting information about tropospheric ozone, aerosols, nitrogen dioxide, and sulfur dioxide, using satellites from NASA and international partners
- Programmatic evolution encouraged integrated approach to atmospheric composition that captured synergies between programs (within NASA, with US and international partners)
- Space measurement programs focusing on troposphere were nurtured (from MAPS through EOS Terra/MOPITT, EOS CHEM/Aura, to new approaches for geostationary observations: TEMPO)

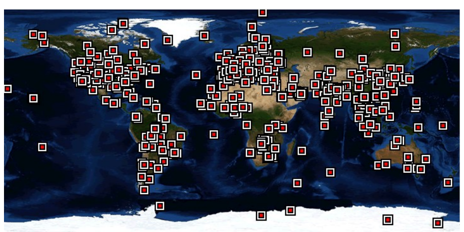

Earth Science Missions and Instruments
Formulation
Implementation
Primary Ops
Extended Ops
Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)
Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF
Landsat 9,
TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA's DSCOVR)
QuikSCAT
EO-1
Landsat 7
(USGS)
Terra
SMAP
Suomi NPP
(NOAA)
Aqua
CloudSat
Landsat 8
(USGS)
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2
Yellow Circles/Ellipses represent missions with significant focus on atmospheric composition

Examples of Contributing Activities

Surface-Based Measurement Networks

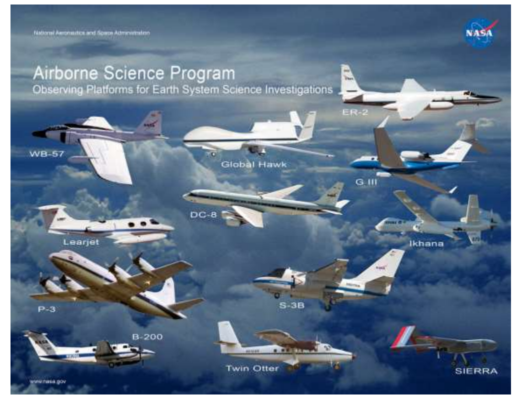
MPLNet

SHADOZ

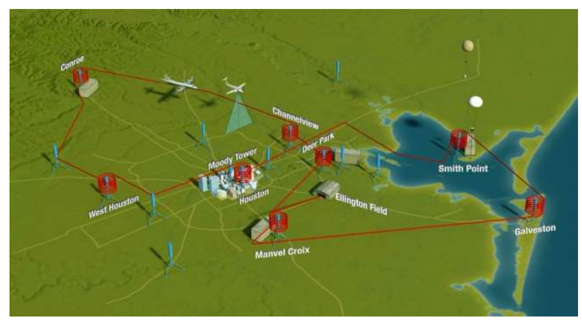


AERONET

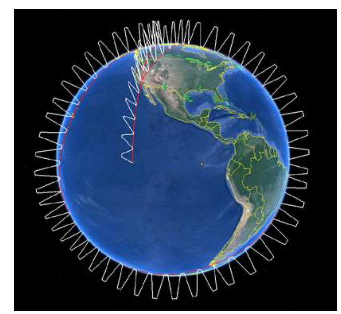
NASA Airborne Science Fleet



DISCOVER-AQ Mission

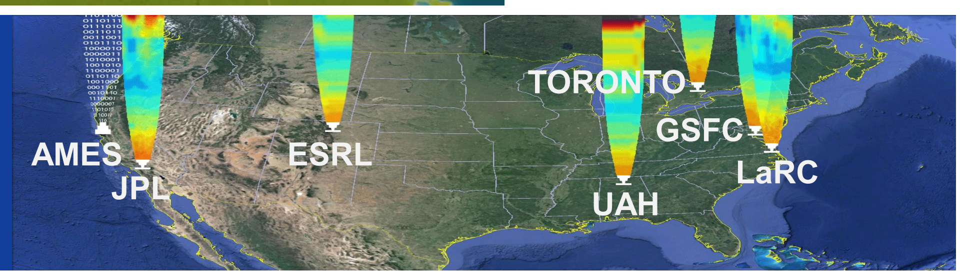


AToM Mission



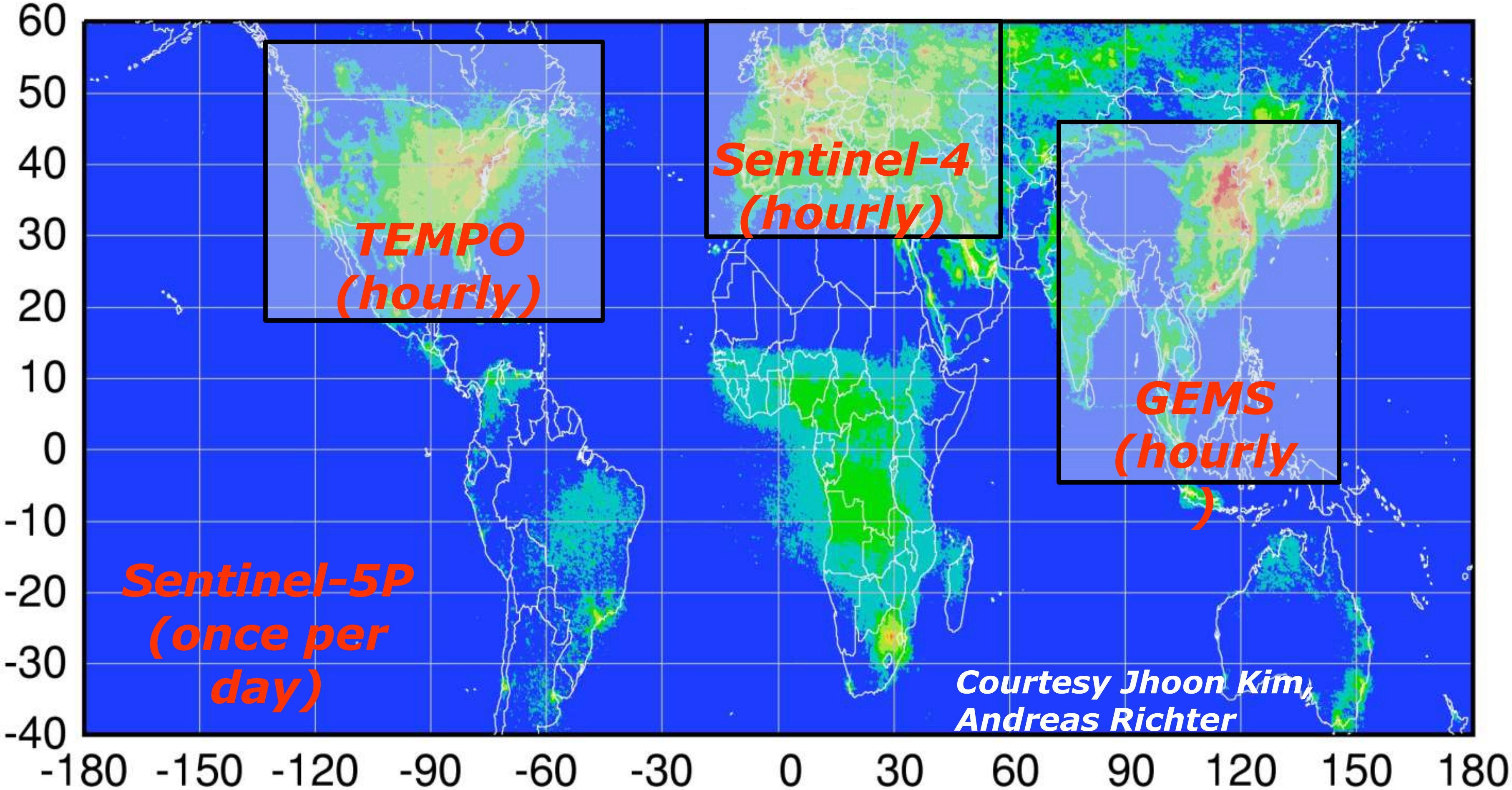
TOLNet

Tropospheric Ozone LIDAR Network



Global pollution monitoring constellation:

Tropospheric chemistry missions funded for launch 2016–2021

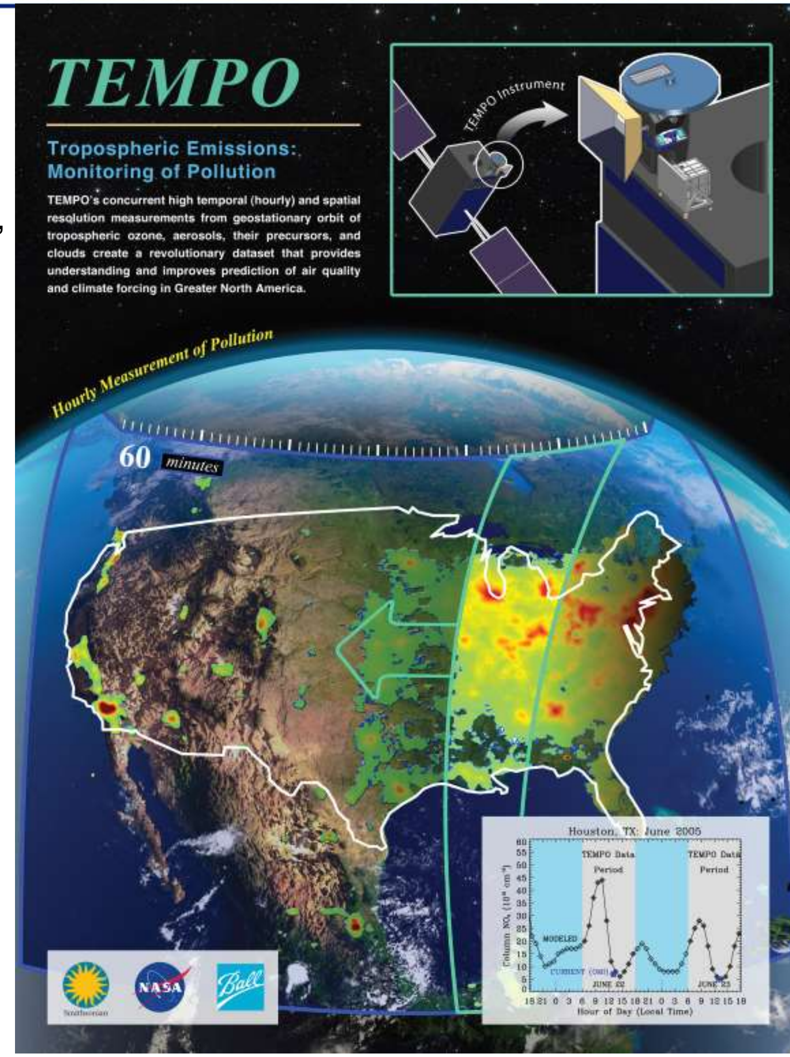


Policy-relevant science and environmental services enabled by common observations

- Improved emissions, at common confidence levels, over industrialized Northern Hemisphere
- Improved air quality forecasts and assimilation systems
- Improved assessment, e.g., observations to support United Nations Convention on Long Range Transboundary Air Pollution

Hourly atmospheric pollution from geostationary Earth orbit

PI: Kelly Chance, Smithsonian Astrophysical Observatory
Instrument Development: Ball Aerospace
Project Management: NASA LaRC
Other Institutions: NASA GSFC, NOAA, EPA, NCAR, Harvard, UC Berkeley, St. Louis U, U Alabama Huntsville, U Nebraska, RT Solutions, Carr Astronautics
International collaboration: Korea, U.K., ESA, Canada, Mexico



Selected Nov. 2012 as NASA's first Earth Venture Instrument

- Instrument being implemented, delivery May 2017
- NASA will arrange hosting on commercial geostationary communications satellite with launch expected NET 11/2018

Provides hourly daylight observations to capture rapidly varying emissions & chemistry important for air quality

- UV/visible grating spectrometer to measure key elements in tropospheric ozone and aerosol pollution
- Exploits extensive measurement heritage from LEO missions
- Distinguishes boundary layer from free tropospheric & stratospheric ozone

Aligned with Earth Science Decadal Survey recommendations

- Makes many of the GEO-CAPE atmosphere measurements
- Responds to the phased implementation recommendation of GEO-CAPE mission design team

North American component of an international constellation for air quality observations

NASA Air Quality Applied Sciences Team (AQAST)

http://aqast.org

AQAST was created to serve the needs of US air quality management through the use of Earth Science satellite observations, models, and latest scientific knowledge.

AQAST consists of 19 members and is chaired by Daniel Jacob (Harvard). Members have expertise in the wide array of Earth Science tools and data sets available from NASA and other agencies.

Team Members:

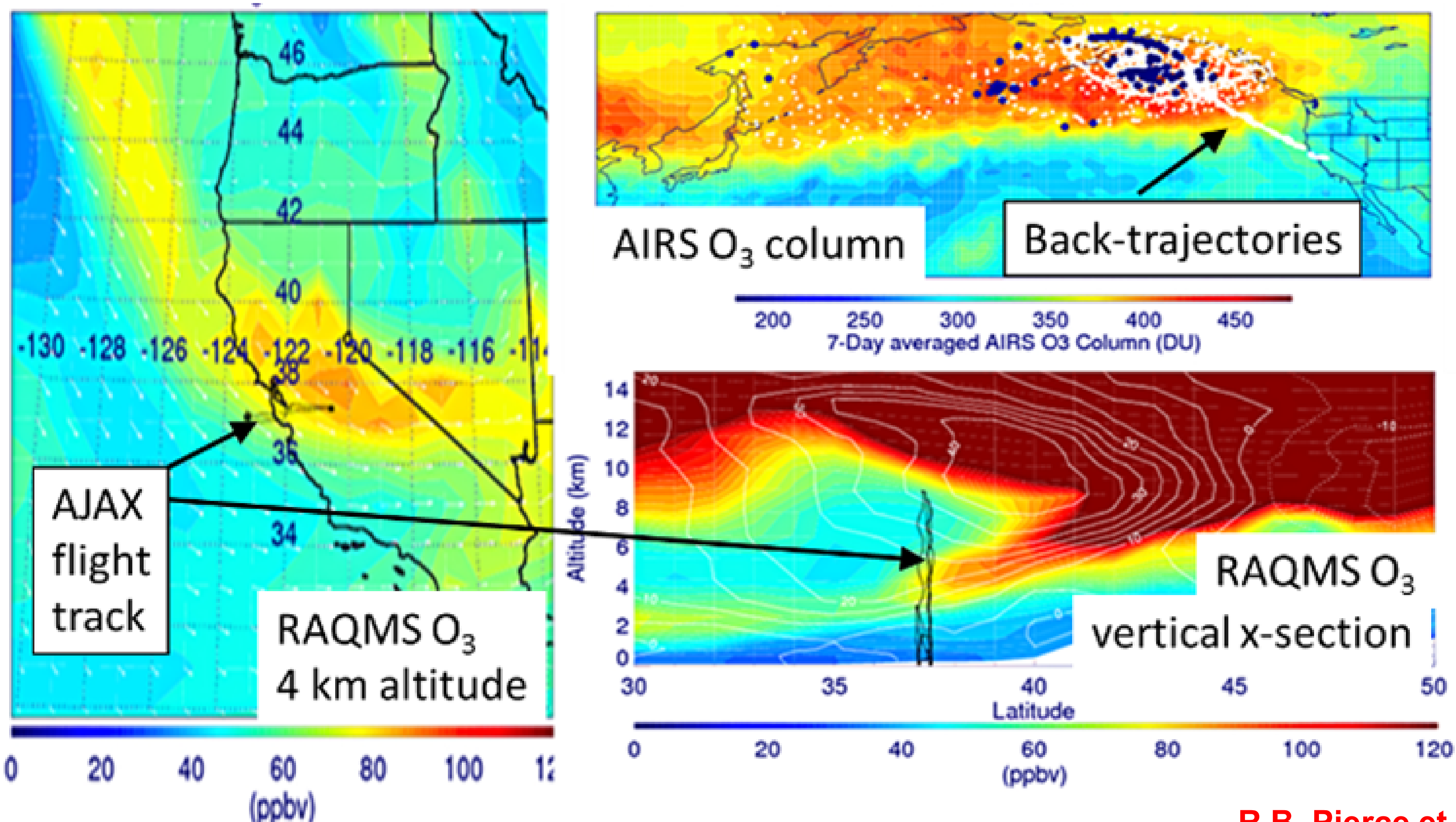
- » Work long-term applications projects
- » Support short-term, quick-response efforts (Tiger Teams)

All AQAST projects are conducted in close partnership with air quality management partners.

ROSES 2015 A.46: H-AQAST
Selections To Be Announced in July 2016

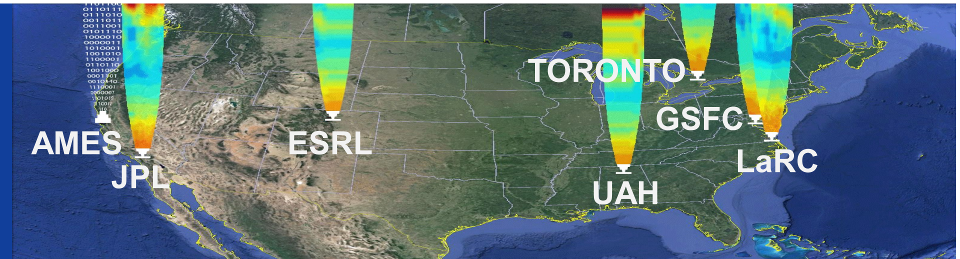
AQAST: Wyoming Exceptional Event Demonstration

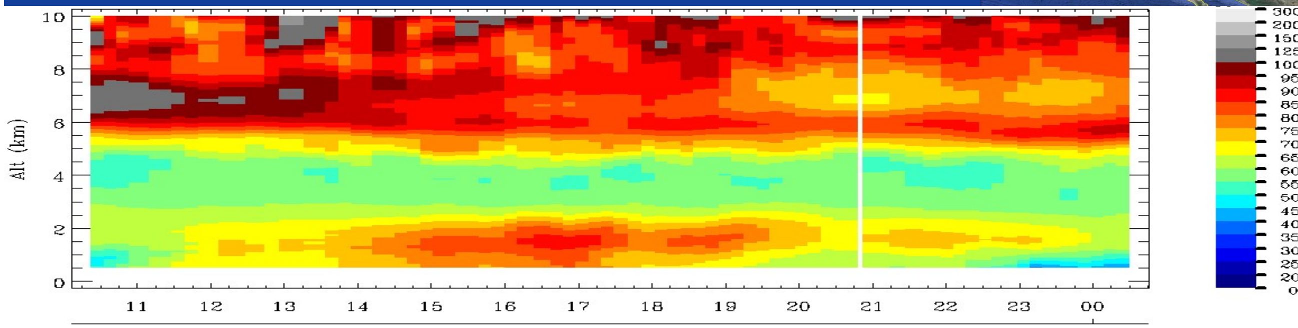
Wyoming DEQ/AQD used RAQMS ozone analyses utilizing Aqua/AIRS data to issue an exceptional event demonstration package to the EPA for an ozone exceedance at Thunder Basin, June 6, 2012. This ozone stratospheric intrusion event was documented by the NASA AJAX flight campaign. EPA accepted in Summer 2014!



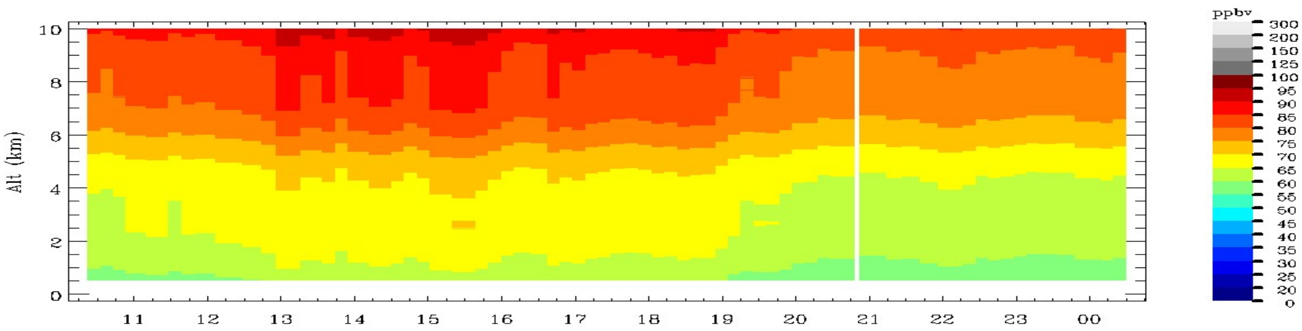
R.B. Pierce et al.

TOLNet Complements TEMPO

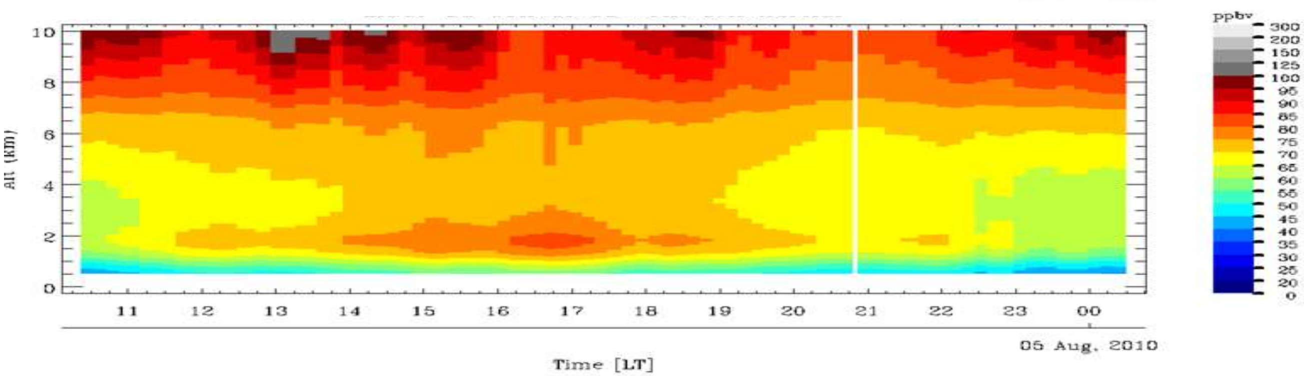




TOLNet/RO_3QET observation at Huntsville on Aug. 4, 2010. Note distinct upper troposphere and PBL layers.



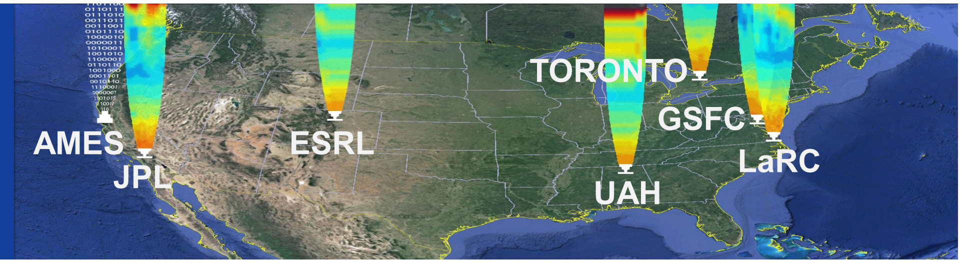
RO_3QET observation convolved with **TEMPO UV** averaging kernel to simulate the space-borne observation, which captures most of the UT layer but little of the PBL.



RO_3QET observation convolved with **TEMPO UV & Visible** enhances the fidelity of both UT and PBL layers, but does not capture the lowest 1km very well. X. Liu et al.

Conclusion: TOLNet provides measurements to not only validate TEMPO, but also to complement TEMPO, especially in the PBL.

TOLNet Motivation and Objectives



Motivation:

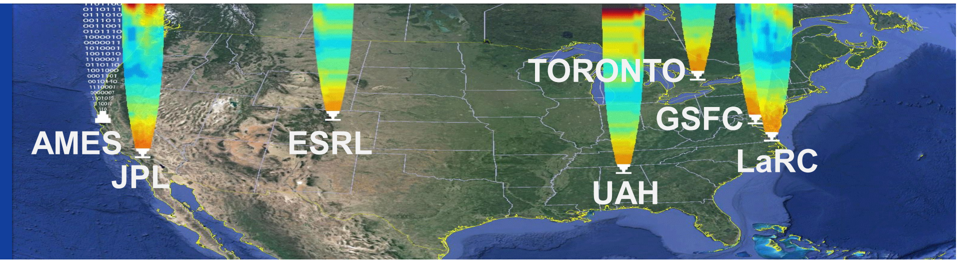
Prepare to make best use of next-generation-satellite troposphericozone observations by advancing the understanding of processes driving the spatial and temporal variability of ozone throughout the troposphere

- **Synoptic processes** such as stratosphere-troposphere exchange, long-range pollution transport, and large-scale stagnation [timescale: days to several hours]
- **Mesoscale processes** such as diurnal land/water boundary cycles, low-level jets, and orographic venting [timescale: hours]
- **Local scale processes** including exchange between the boundary layer and the free troposphere, episodic precursor emissions, and convection [timescale: sub-hourly]

Objectives:

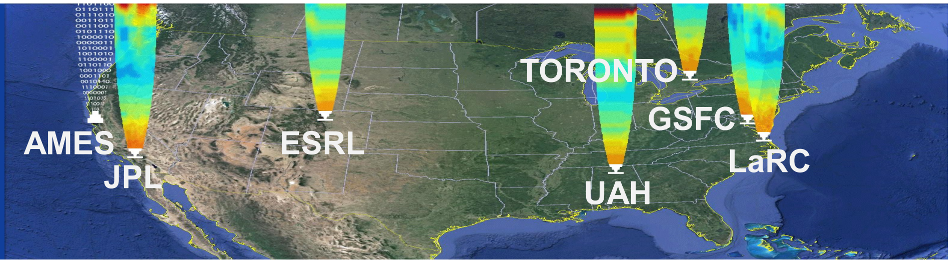
- Provide coordinated **high-resolution, time-height measurements of ozone** from near-surface to upper troposphere for air-quality/chemical/transport model improvement and satellite retrieval validation
- **Exploit synergies** with EVS-1 DISCOVER-AQ, EVI-1 TEMPO, GEO-CAPE studies, and existing routine observations to advance understanding of processes controlling regional air quality and chemistry
- Develop recommendations for **lowering the cost and improving the robustness** of ozone lidar systems to better enable their capability for addressing the needs of NASA, NOAA, EPA, and State/local AQ agencies

TOLNet Accomplishments



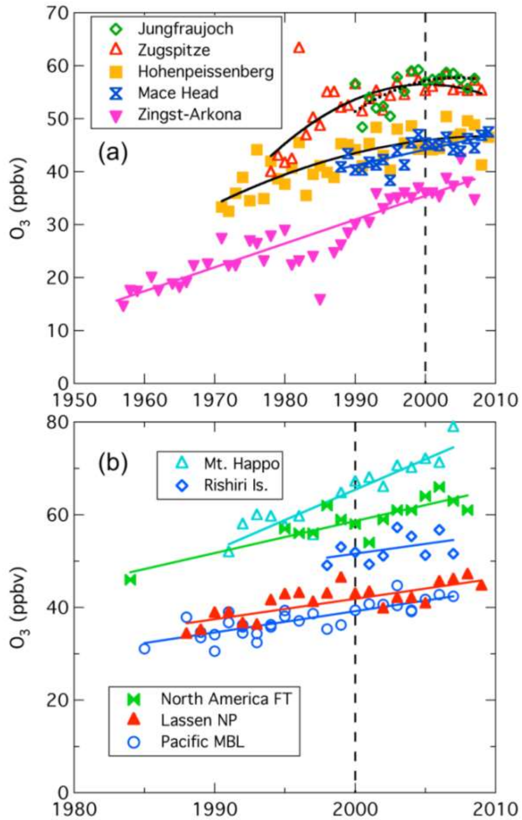
- Established stable, **well-defined funding** from NASA and NOAA with additional leverage
- Operated **6 lidars** (4 mobile, 2 scanning) with **5-10% accuracy**, low minimum altitude, all measure PBL+, 3 measure UTLS, all with complementary instruments nearby.
- Participated in **8 field campaigns** (6 by ESRL/CSD, 2 by GSFC & LaRC, 1 by UAH) including 3 lidars at BAO and at **DISCOVER-AQ** Colorado and single lidars in CA, CO, UT, TX, NV, MD, VA, and AL
- Demonstrated **resiliency** to overcome significant deployment difficulties (lightning strikes, chillers, etc.)
- Showed **TOLNet scientific capability** (e.g., Langford TOPAZ/HSRL/HRDL RL entrainment; Sullivan M/M STE morphology; Huang LES PBL development study; All PBL and FT laminar morphology; Sullivan, Langford, Senff, Kuang Sfc/PBL/FT/Strat laminar structure and disconnects including DAQ mandate col/sfc; and other studies
- Engaged in **national-agenda discussions** (NSF/ACCORD, CA/TOA, NASA/DS) and NASA TEMPO science team.
- **Established guidelines** to quantify standard vertical resolution, measurement uncertainties, and retrieval accuracy
- At **KORUS** 2016 and will go to **SJV 2016 summer**
- Collaborating with NASA/MSFC/SPoRT as **Early Adopter** with TEMPO
- Established standard data protocol and **public archive** http://www-air.larc.nasa.gov/missions/TOLNet/

Message from Terry Keating/USEPA/OAR to TOLNET 2015



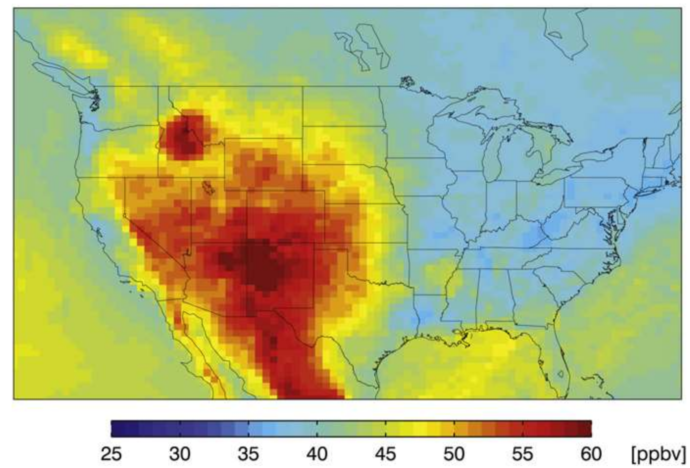
- A tightening vise: O_3 background is going up, O_3 standards are coming down
- Air-quality management requires source apportionment.
- Source apportionment requires improving models.
- Improving models will require more observations of processes aloft.
- There is still time to inform policy development.
- Need to focus delivery of data and analysis to air quality modelers at federal, state, and local level.

Increasing Background Ozone: A Major Challenge in the Western U.S.



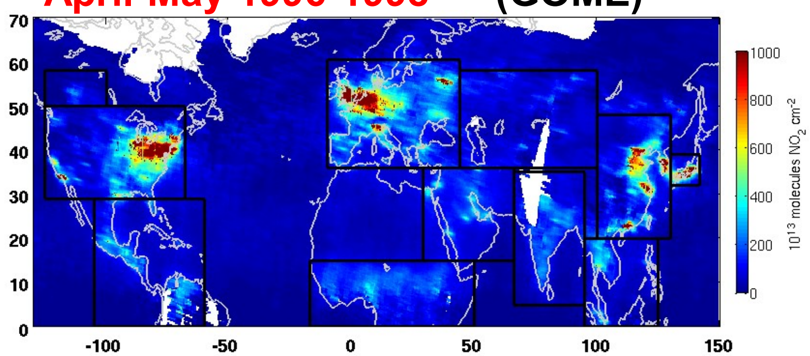
←Average springtime O_3 levels at remote or high-altitude sites across the Northern Hemisphere have shown very consistent trends. These trends suggest that baseline O_3 in northern mid-latitudes has increased by at least a factor of two since 1950. (HTAP, 2010)

→Annual 4th highest daily maximum 8-hour average O_3 (2006-8) due to emissions outside of North America is near or equal to the range being considered for the NAAQS. (Zhang et al 2011)

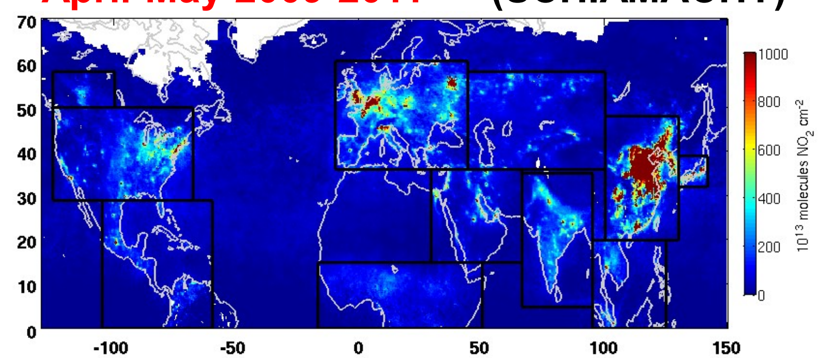


↓Satellite observations of NO_2 show that over the last decade emissions of O_3 precursors in US and EU have declined while doubling in China. (Cooper, 2013)

April-May 1996-1998 **(GOME)**



April-May 2009-2011 **(SCHIAMACHY)**



ATMOSPHERE

Challenges of a lowered U.S. ozone standard

Source attribution science can help areas of the U.S. west

By Owen R. Cooper,[1,2*] Andrew O. Langford,[2] David D. Parrish,[1,2] David W. Fahey[2]

THE CHALLENGE

EPA has stated that "[e]xisting and up-coming EPA regulations and guidance will assist states in ensuring background ozone does not create unnecessary control obligations".

However, these mechanisms require states and EPA to be able to quantify the overall contribution and sources of background ozone.

The role of scientists is to inform the decision-making by conducting research to accurately quantify background ozone.

The challenges are model accuracy and limited observations of baseline ozone, which require further development and enhancement in order to improve the quantification of background ozone.

MOTIVATION

From both scientific and regulatory points of view, a lower ozone standard will motivate air quality– control planners to seek more accurate and precise attribution of observed ozone to local, upwind, and stratospheric sources of ozone to determine how much domestic emissions must be reduced in order to attain that standard….

…..Accurate quantification of background ozone under this new paradigm would require enhanced baseline ozone observations at a spatial density and temporal frequency adequate for evaluating and improving the models.

Free tropospheric monitoring

- Ozonesondes
- Lidar (TOLNet)
- Research and commercial aircraft (IAGOS, NOAA GMD)

At Earth's surface, ozone is an air pollutant that causes respiratory health effects in humans and impairs plant growth and productivity (1). The Clean Air Act (CAA) of 1970 mandates that the U.S. Environmental Protection Agency (EPA) assess the ozone standard every 5 years and revise when necessary to protect human health.

POLICY With a decision expected in October 2015 as to whether the standard will be toughened, we discuss limitations of ozone and precursor observations that hinder the ability of state and local air pollution–control agencies to accurately attribute sources of ozone within their jurisdictions. Attaining a lower standard may be particularly challenging in high elevations of the western United States, which are more likely to be affected by ozone that has been transported long distances or that originated in the stratosphere.

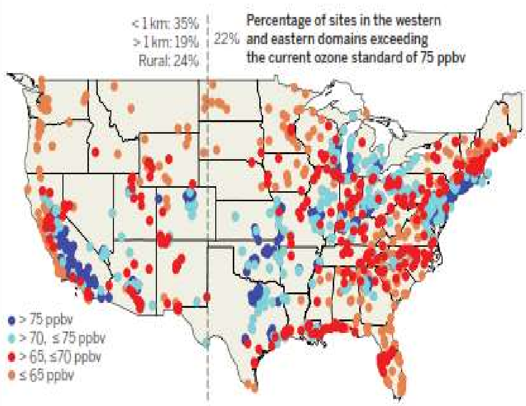
Understanding the origins of surface ozone is complicated by its multitude of sources. Ozone is transported to the surface from the natural reservoir in the stratosphere or produced from precursor gases [nitrogen oxides (NO_x) and volatile organic compounds] that react in the presence of sunlight. Ozone precursors have natural sources—such as vegetation, wildfires, and lightning—and are also emitted by human activity—such as combustion of fossil fuels and human-caused biomass burning.

The current primary (health-based) EPA standard is 75 parts per billion by volume (ppbv), with 227 U.S. counties, home to 123 million people, classified as not having attained the standard (www.epa.gov/airquality/greenbook/index.html). In November 2014, EPA proposed a revised primary ozone standard in the range of 65 to 70 ppbv in order to improve public health protection (2). The most recent ozone "design values" were used to determine whether ozone observations comply with the standard (which is based on

the 3-year average of the fou… maximum 8-hour ozone a… year) at all EPA-approved o… sites (see the chart). The hi… in large urban areas. Recent… to 2013 reveal that 358 and 5… design values that would e… ozone standard of 70 and … tively (www.epa.gov/groundl… html). The good news is th… values are declining becaus… ductions in precursor emi… from regulations such as th… a state implementation plan… across 22 eastern states in 2… tionwide Tier 2 Vehicle and… Program that began in 20… these emissions trends to c… 2025 owing to already pron… tions (3).

Although ozone design v… ally declining across the U… trends are weakest at rura… sites in the western United… above sea level) (4). One p… is greater exposure to e… line" ozone that flows ac… Pacific Ocean or is transpo… from the lower stratosphe…

EPA-approved ozone…



Ozone design values at all EPA ozone monitors operating during 2011–2013. The vertical dashed line separates the high-elevation regions (>1.5 km) of the west from the east. Western sites are divided into those above and below 1 km above sea level, with a separate overlapping category of rural sites. [Ozone values source: www.epa.gov/airtrends/values.html]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309, USA. [2]Chemical Sciences Division, NOAA Earth System Research Laboratory, Boulder, CO 80305, USA.
*Corresponding author. E-mail: owen.r.cooper@noaa.gov

(10–12) and ozone observations above the California coast (9) and rural Nevada (6) also indicate substantial baseline ozone at low-elevation rural and urban (<1.5 km) sites in the western United States.

EPA is aware of ozone variations across the western United States and has con… …arch for the latest …y (1, 3) by focusing …orth American back… …0, 11). This is ozone …e absence of any an… …recursor emissions …lthough background …ponent of baseline … baseline ozone be… …ured by instruments …d by global-scale at… …-transport models. …cates the proportion …erican ozone that is … domestic air pollu…s; these estimates …ality managers how …ns must be reduced … ozone standard. Al…ires EPA to set the …els requisite to pro… … welfare without re… … the pollutant, EPA … ozone as an impor…tand and quantify in …ation policies. Using …-regional air-quality … EPA estimated that …kes substantial con…zone in the western … Seasonal (April to …round levels ranged …oss much of Arizona, …v Mexico, Utah, and Wyoming, with some individual days approaching the range of the proposed standard (i.e., 65 to 70 ppbv).

EPA has stated that "[e]xisting and upcoming EPA regulations and guidance will assist states in ensuring background ozone does not create unnecessary control obligations" (13). However, these mechanisms require states and EPA to be able to quantify the overall contribution and sources of background ozone. The role of scientists is to inform the decision-making by conducting research to accurately quantify background ozone. The challenges are model accuracy and limited observations of baseline ozone, which require further development and enhancement in order to improve the quantification of background ozone. A comparison of two global models shows that they differ in their estimates of monthly mean background ozone by as much as 10 ppbv and produce different seasonal cycles (12). Global models also have deficiencies in re-

producing long-term observed ozone trends …

From both scientific and regulatory points of view, a lower ozone standard will motivate air quality-control planners to seek more accurate and precise attribution of observed ozone to local, upwind, and stratospheric sources of ozone to determine how much domestic emissions must be reduced in order to attain that standard. A lower ozone standard will also increase the probability that the standard will be exceeded in springtime, which would require the attribution of ozone episodes beyond the typical summertime period of concern. Accurate quantification of background ozone under this new paradigm would require enhanced baseline ozone observations at a spatial density and temporal frequency adequate for evaluating and improving the models. Once the models can replicate baseline ozone, greater confidence can be placed in their estimates of background and locally produced ozone.

Additional observations include routine vertical ozone profiles at multiple coastal and inland sites using balloon-borne ozonesondes, ground-based ozone lidars, or, possibly, commercial aircraft. Related options include augmenting the U.S. Tropospheric Ozone Lidar Network (TOLNet), the U.S. National Oceanic and Atmospheric Administration (NOAA) Global Greenhouse Gas Reference Network aircraft program, or the European In-Service Aircraft for a Global Observing System (IAGOS). New

REFERENCES AND NOTES

1. EPA, Policy Assessment for Ozone (EPA-452/R-14-006, EPA, Washington, DC, 2014); www.epa.gov/ttn/naaqs/standards/ozone/s_o3_index.html.
2. Office of Air and Radiation, EPA, "National ambient air quality standards for ozone; Proposed rule," 45 Code of Federal Regulations (C.F.R.), Parts 50, 51, 52, 53, and 58 (2014).
3. EPA, Regulatory Impact Analysis of the Proposed Revisions to the National Ambient Air Quality Standards for Ground-…

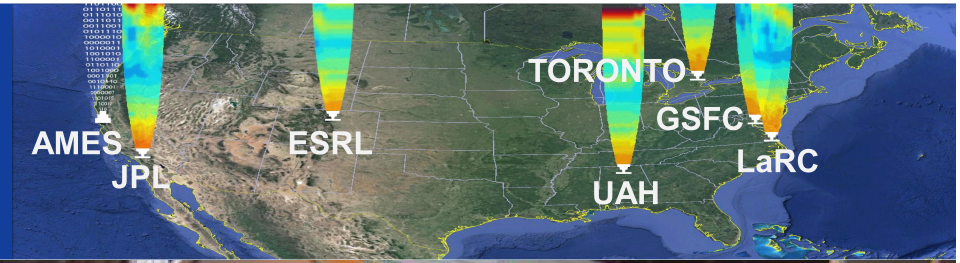
15. L. E. Gratz, D. A. Jaffe, J. R. Hee, Atmos. Environ. 109, 323 (2015).

ACKNOWLEDGMENTS

The opinions expressed here are those of the authors and not their institutions. The authors acknowledge support from NOAA's Health of the Atmosphere and Atmospheric Chemistry and Climate Programs. T. Keating and G. Tonnesen, U.S. EPA, provided comments.

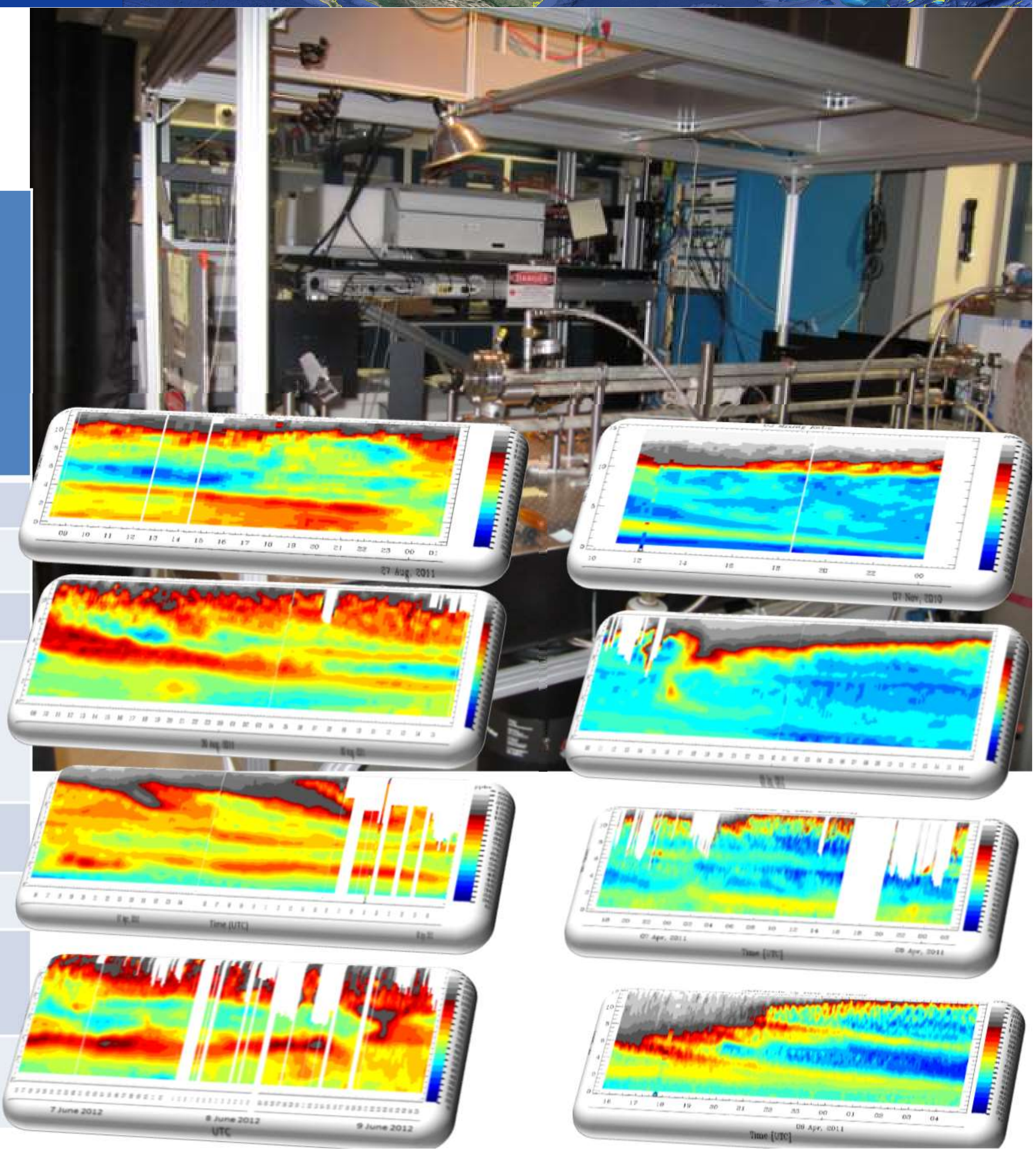
10.1126/science.aaa5748

TOLNet/UAH RO$_3$QET
Ground-based O3 lidar

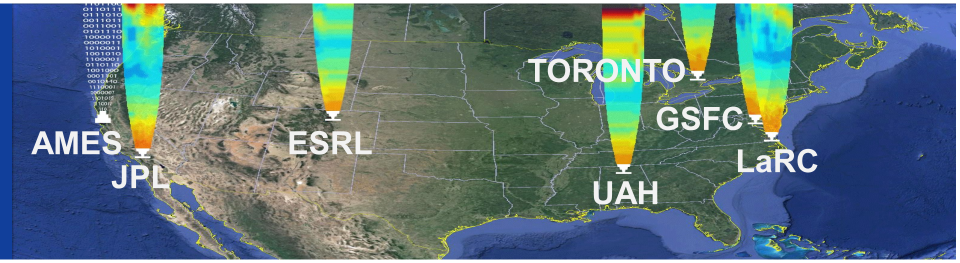


THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

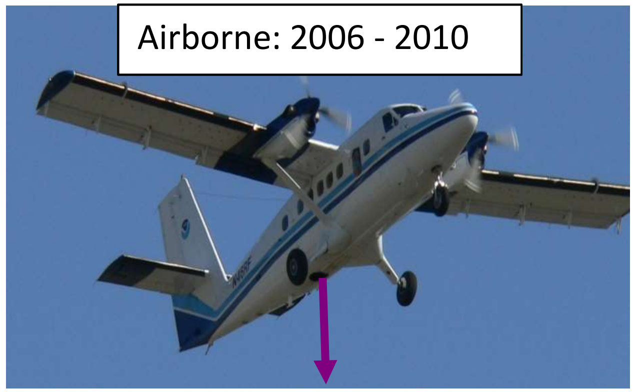
Name	RO$_3$QET (Rocket-city O3 Quality Evaluation in theTroposphere) lidar
Affiliation	UAH
Host location	Huntsville, AL
Set-up	Fixed-location
Transmitter type	Quadruple Nd:YAG pumped Raman laser
Wavelength (nm)	289, 299
Receiver size (cm)	40, 10, 2.5, 2-axis scanner
Measurable range (km AGL)	0.1-12
Reference	[Kuang et al., 2011, 2013]

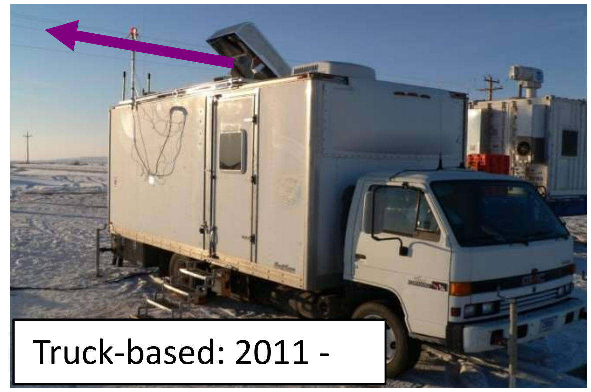


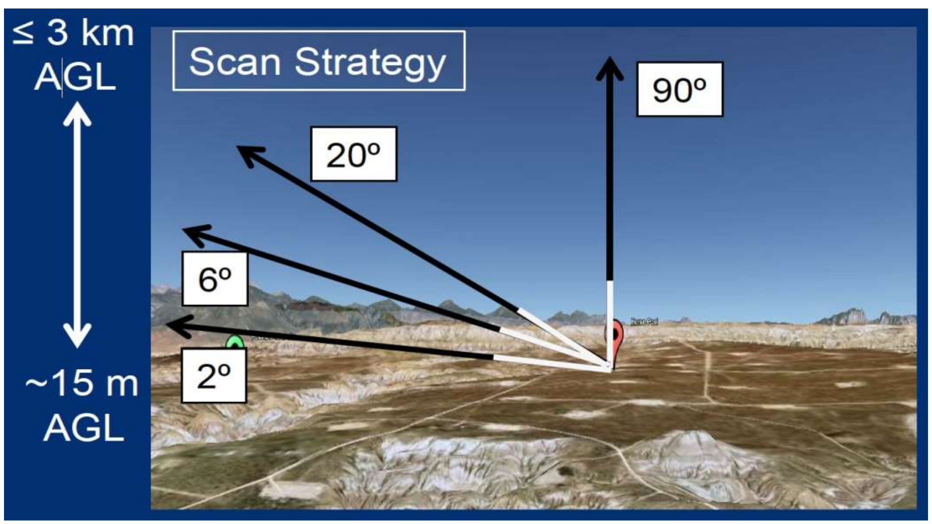
TOLNet/NOAA/ESRL TOPAZ Ozone Lidar (TOPAZ = Tunable Optical Profiler for Aerosol and oZone)

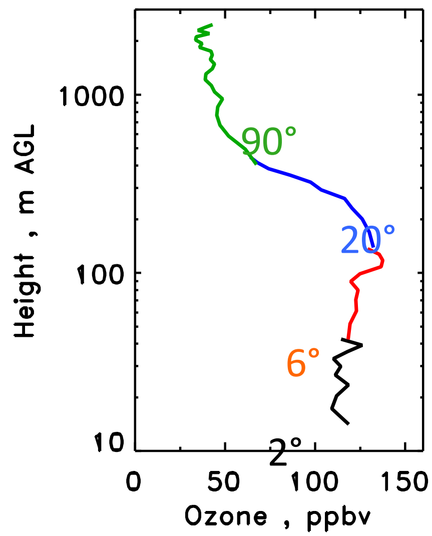


- Tunable UV ozone DIAL
- Based on solid-state Ce:LiCAF laser





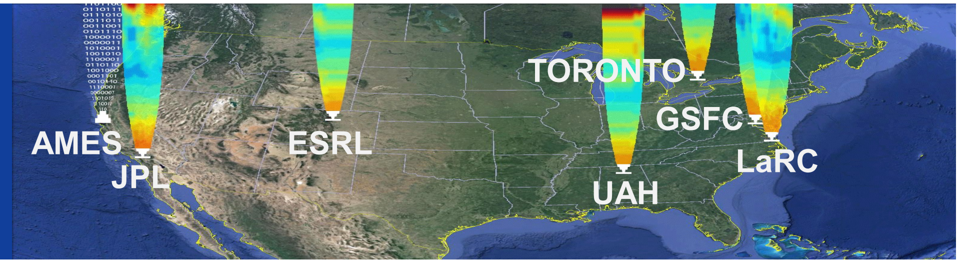




Composite vertical O_3 and aerosol profiles every 5 min

TOLNet

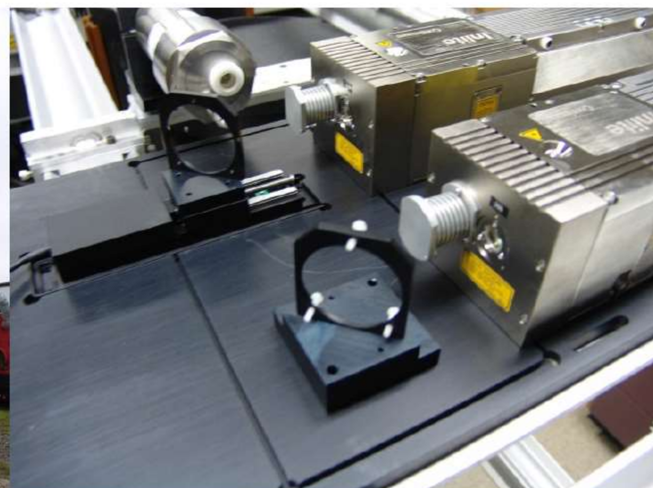
Environment and Climate Change Canada



Environment Canada   Environnement Canada

Canada

Autonomous ozone and aerosol lidar measurements: a synergistic approach to air quality

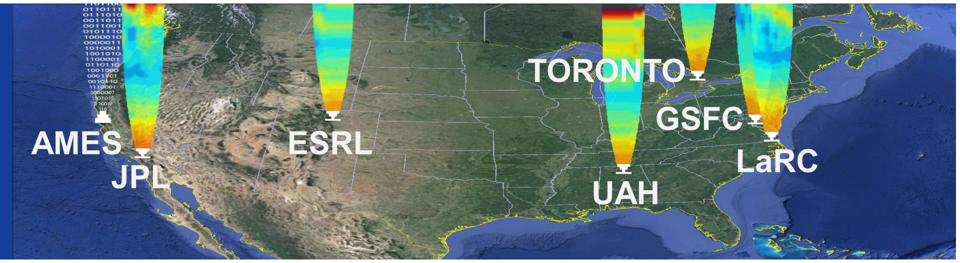


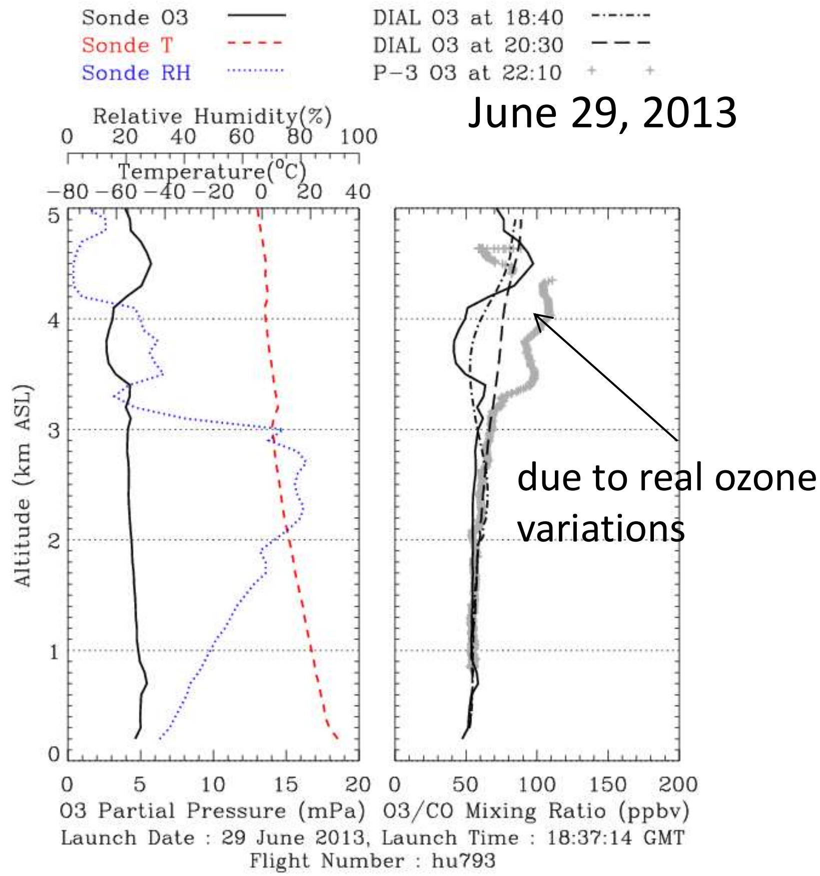
Kevin Strawbridge

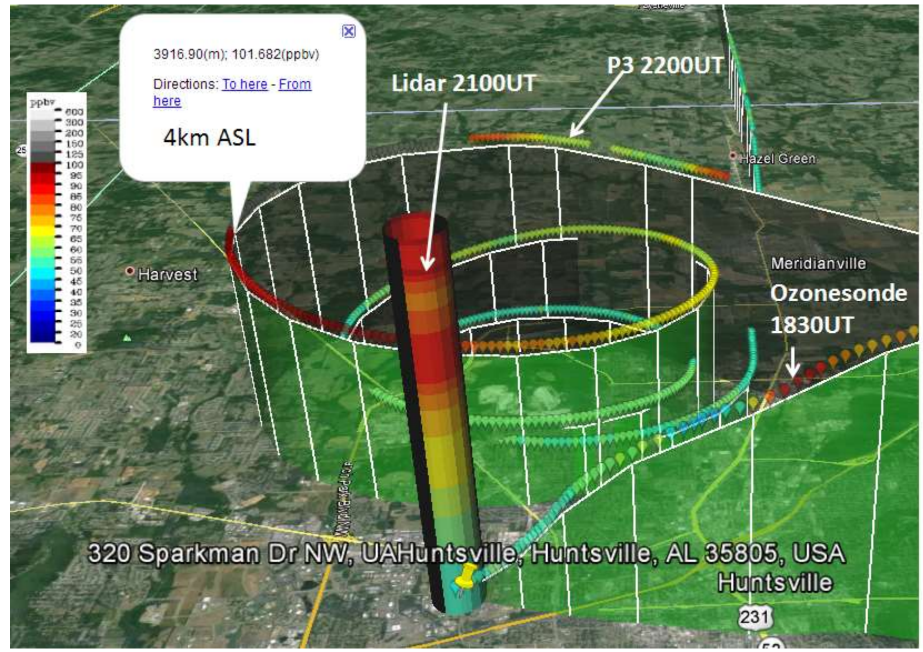
Air Quality Processes Section, Environment Canada

email: Kevin.Strawbridge@ec.gc.ca

TOLNet/UAH RO$_3$QET validation with P-3B and ozonesondes during 2013 SENEX



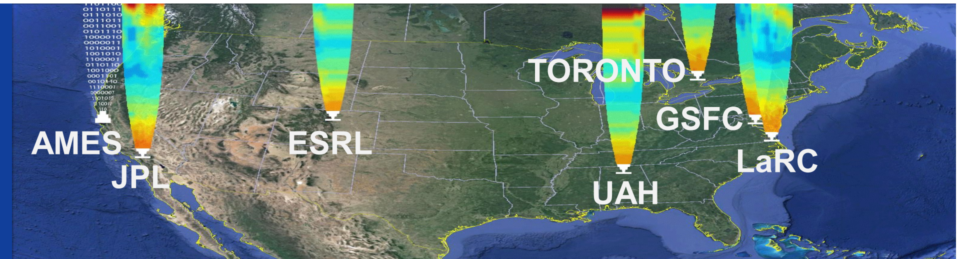


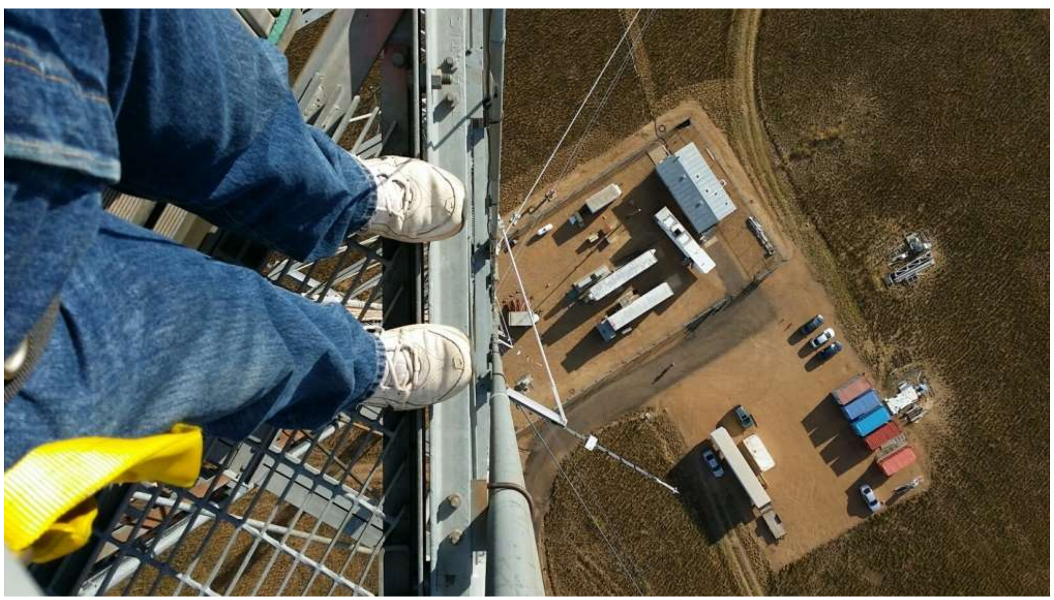


Lidar, sonde, P-3 measured ozone mixing ratio shown on the GOOGLE map.

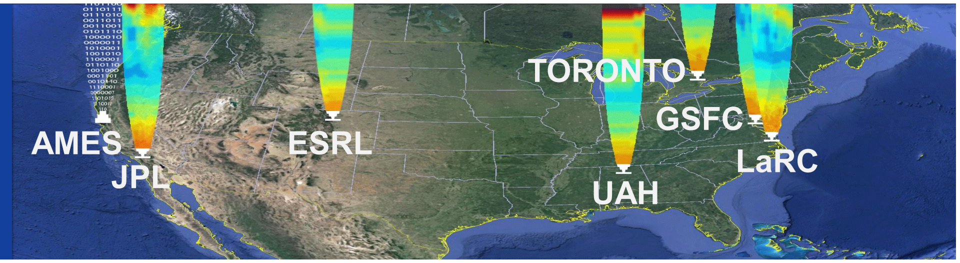
The left panel shows the ozone, temperature, and relative humidity measured by the ozonesonde launched at 18:37 showing atmospheric laminar structure. The right panel shows the comparison of ozone profile measured by the ozonesonde, the profile measured by the P-3, and two DIAL ozone profiles measured at two different times (one close to the ozonesonde launching time and the other close to the time P-3 overpassing Huntsville). <about 8 min for P-3 HSV spiral>

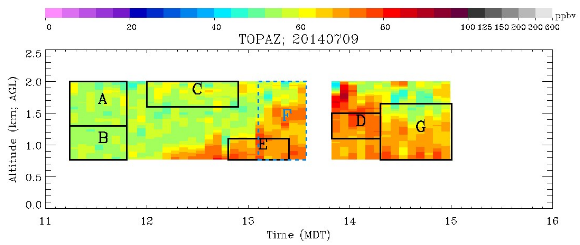
TOLNet validation at BAO before DISCOVER-AQ/Colorado

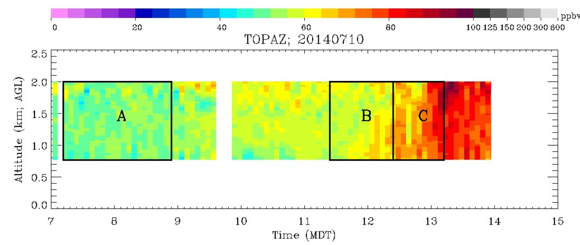


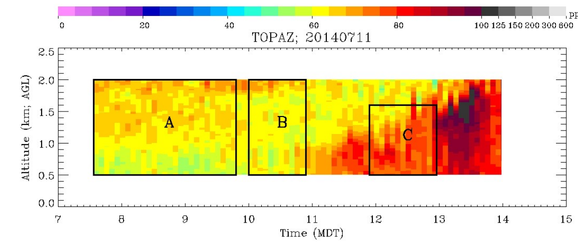


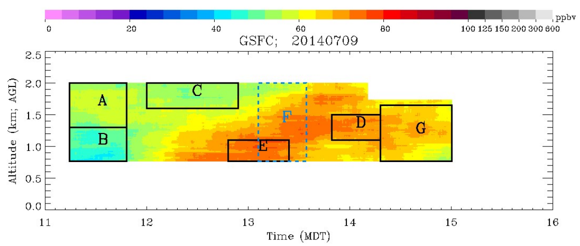
TOPAZ and TROPOZ at BAO
July 9, 10, & 11, 2014

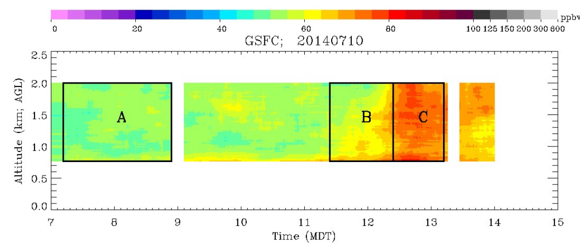


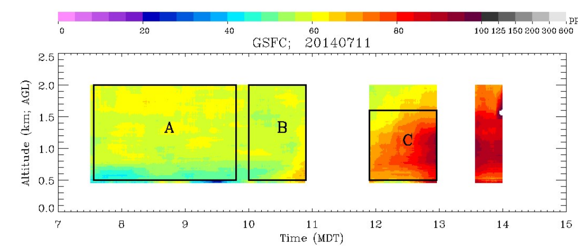




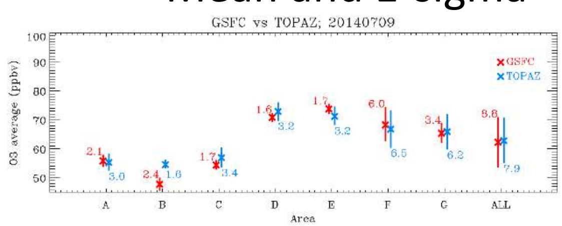




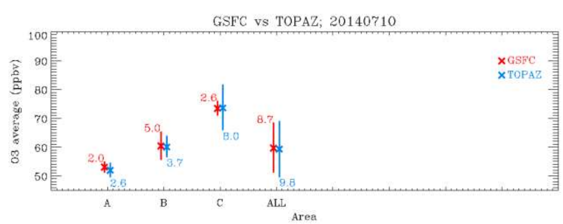




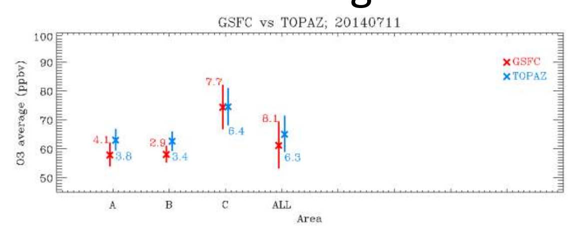
Mean and 1-sigma



Mean and 1-sigma



Mean and 1-sigma



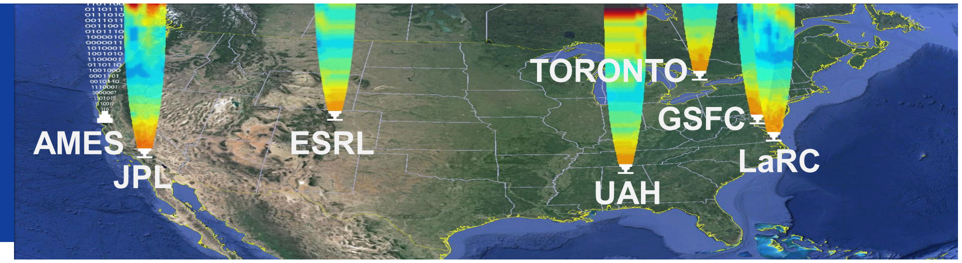
TOPAZ sample size = 30967
mean = 62.6 ppbv
std dev = 8.4 ppbv =13%

TROPOZ sample size = 158203
mean = 60.9 ppbv
std dev = 8.5 ppbv = 14%

Diff. of mean = 3%
Diff. of std dev = 1%

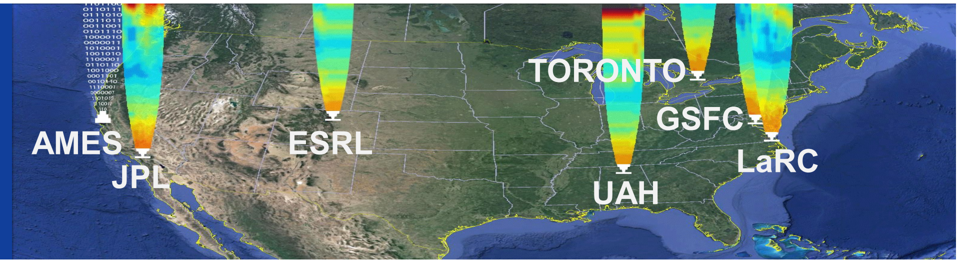
TOLNet

Accuracy-assessment Conclusion



After a large number of intercomparisons and rigorous retrieval-algorithm scrutiny, TOLNet lidars TMF, TOPAZ, RO_3QET, LMOL, and TROPOZ agree with ozonesonde free flights and tether flights (5% instrument accuracy), with CRDS (1% instrument accuracy) on the BAO carriage, and with each other to within ~ 10% over a wide variety of conditions between 20m and 15km and often to better than 5%.

TOLNet/NASA/GSFC TROPOZ lidar provides the vertical connection



Connecting the Satellite and Surface Observations with Ozone Lidar

Tom McGee, John Sullivan, G. Sumnicht, L. Twigg, Anne Thompson

- Instrument designed in late 2012 with funding from Jack Kaye and TOLNet
- Purpose: air quality profile measurements
- Designed/installed inside mobile trailer
- Ozone profile measurements from PBL to ~10 km daytime; 19km nighttime - 10 min integration time
- Participant in NASA DISCOVER AQ and KORUS-AQ

Vision For the Future:

- TropOz ozone profiles will help validate future satellite trop. ozone products (e.g TEMPO, GEOCAPE)
- Deployable for impact studies/campaigns investigating tropospheric ozone profiles (see - Fig 1)
- High-res profiles are obtained nearly continuously (see - Fig 2), which will help address diurnal ozone enhancements, gradients, and chemical composition

Fig 1

Fig 2

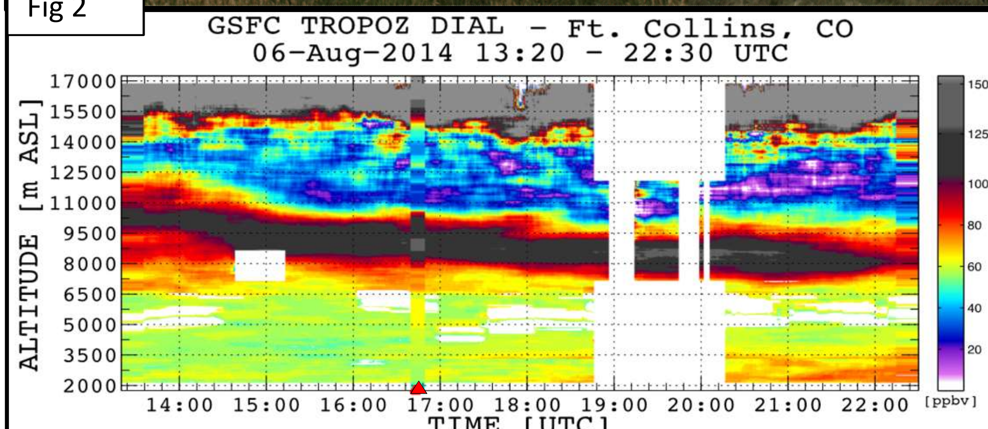
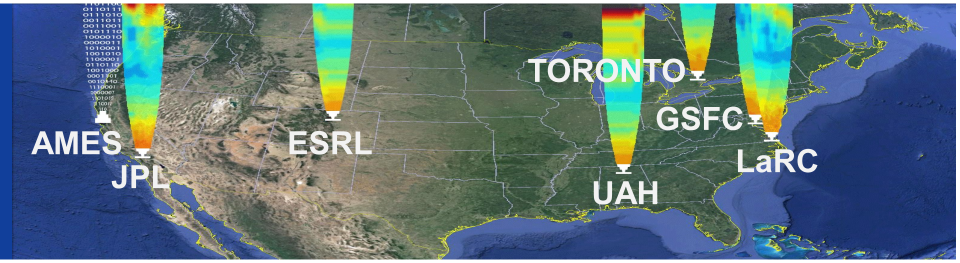
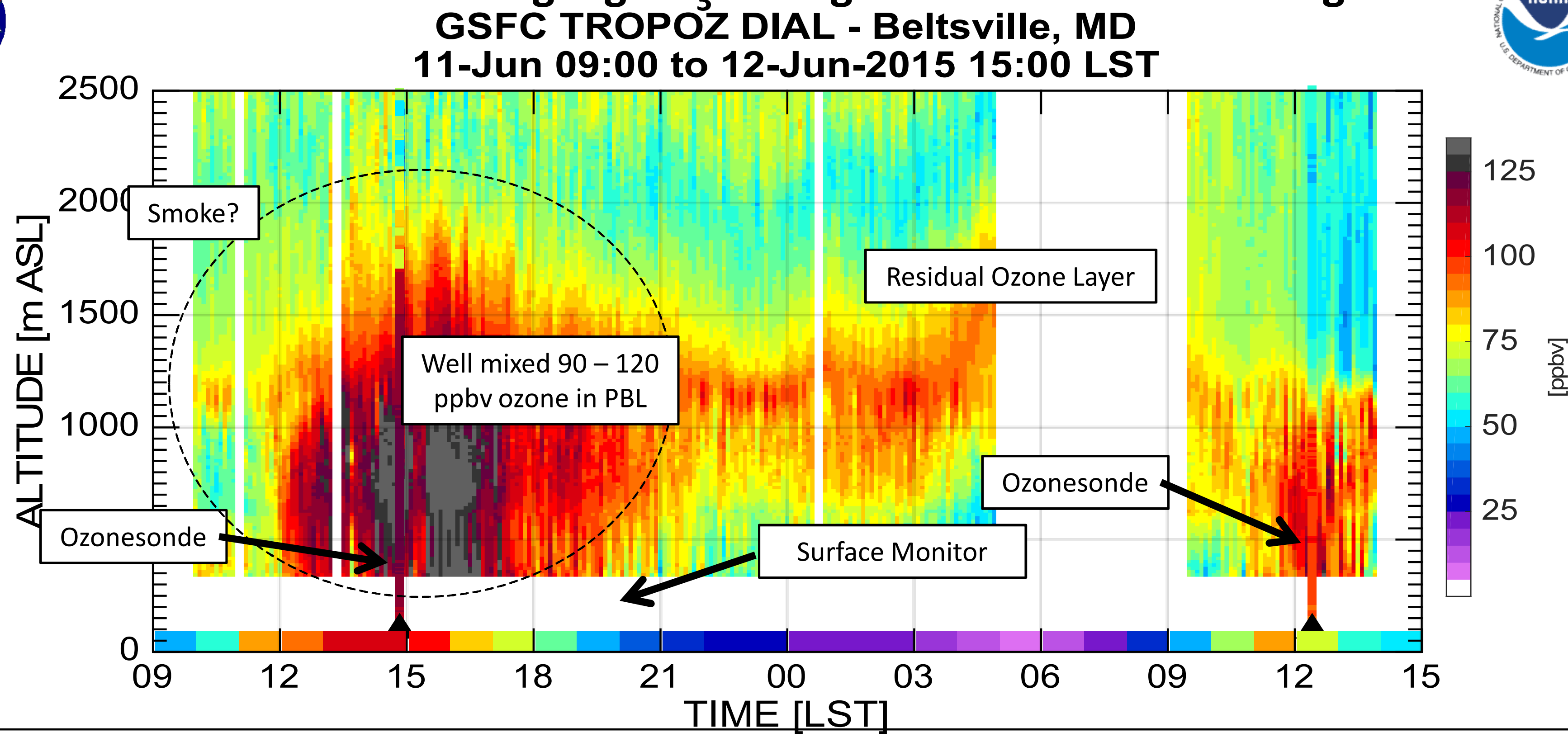


Figure 1 – TropOz at Ft. Collins, CO during DISCOVER AQ 2014.
Figure 2: Ozone time series of stratospheric intrusion (*Sullivan et al., 2015*)

TOLNet/NASA/GSFC TROPOZ
PBL Ozone in Beltsville, MD 2015

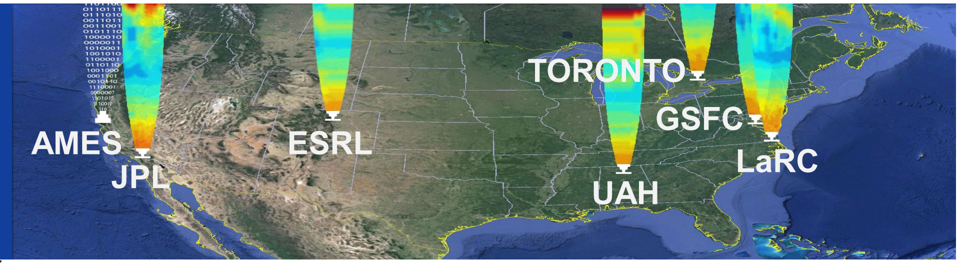


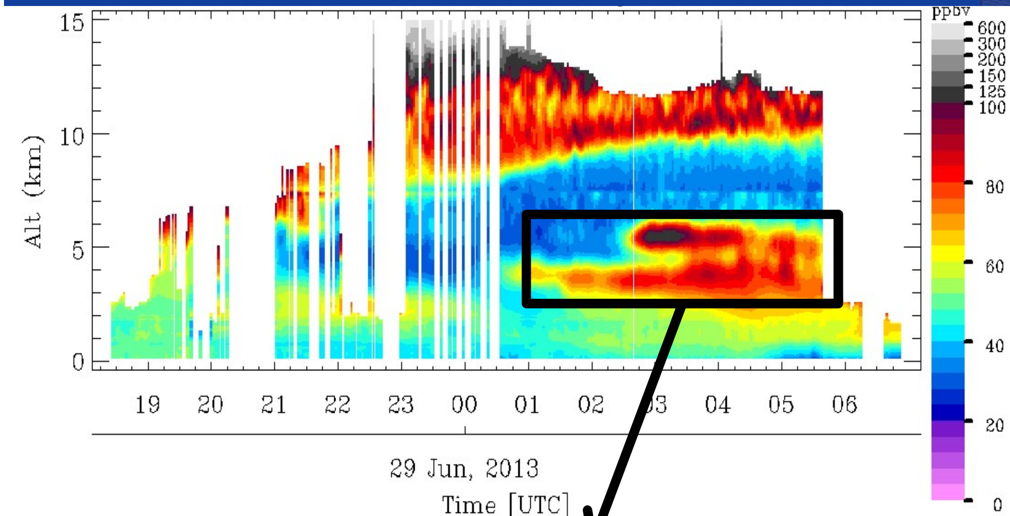
TROPOZ characterizing high O_3 during Summer 2015 in BW region



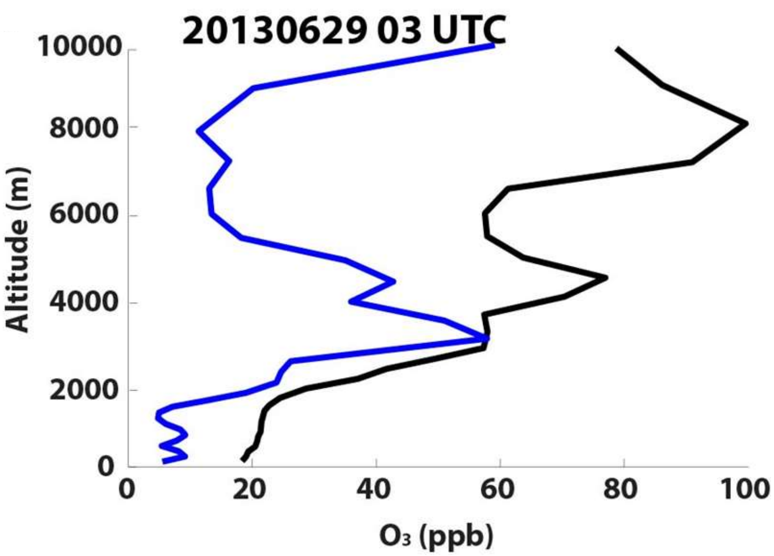
Top: The GSFC TROPOZ was deployed to Beltsville, MD to make measurements in support of Maryland Department of the Environment (MDE) air quality forecasts. On June 10, 2015 (one day before above time-series) heavy smoke originating from Canadian wildfires (most likely from Saskatchewan) impacted the boundary layer throughout the Mid-Atlantic region, bringing additional ozone precursors to the region. The ozone series on June 11, 2015 (above) shows large ozone enhancement with ozone concentrations reaching 90-120 ppbv, which were also verified with the ozonesonde. The impacts at the surface were also observed and several surface monitoring sites, including the Beltsville, MD monitor, exceeded the NAAQS 8-hr 75 ppbv ozone standard. Importantly, this was the worst day for ozone in MD since 2012.

TOLNet/Modeling @ ARC: Evaluating predictions of source attribution

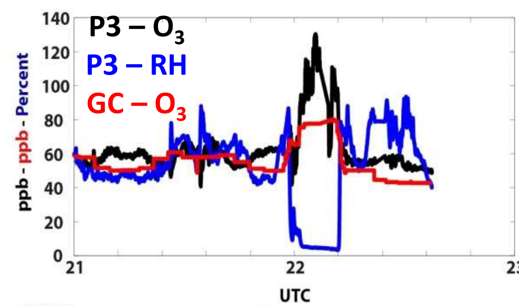


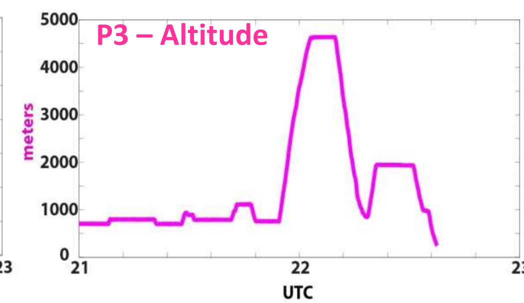


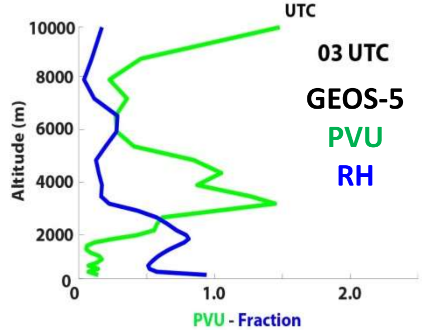
- **Model predictions and measurement data suggest that stratospheric O_3 is likely contributing largely to the vertical region where the model is underestimating TOLNet-measured O_3**
- **Evaluating the model with vertical information from lidars provides information about what sources/processes could be improved within the model**



Model-predicted magnitude of O_3 contribution from BG + stratospheric transport and just stratospheric transport

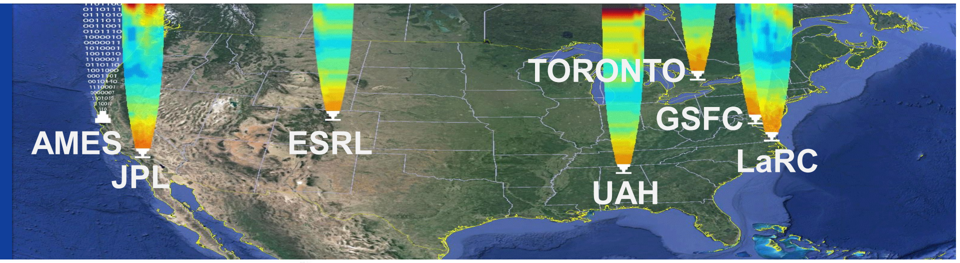


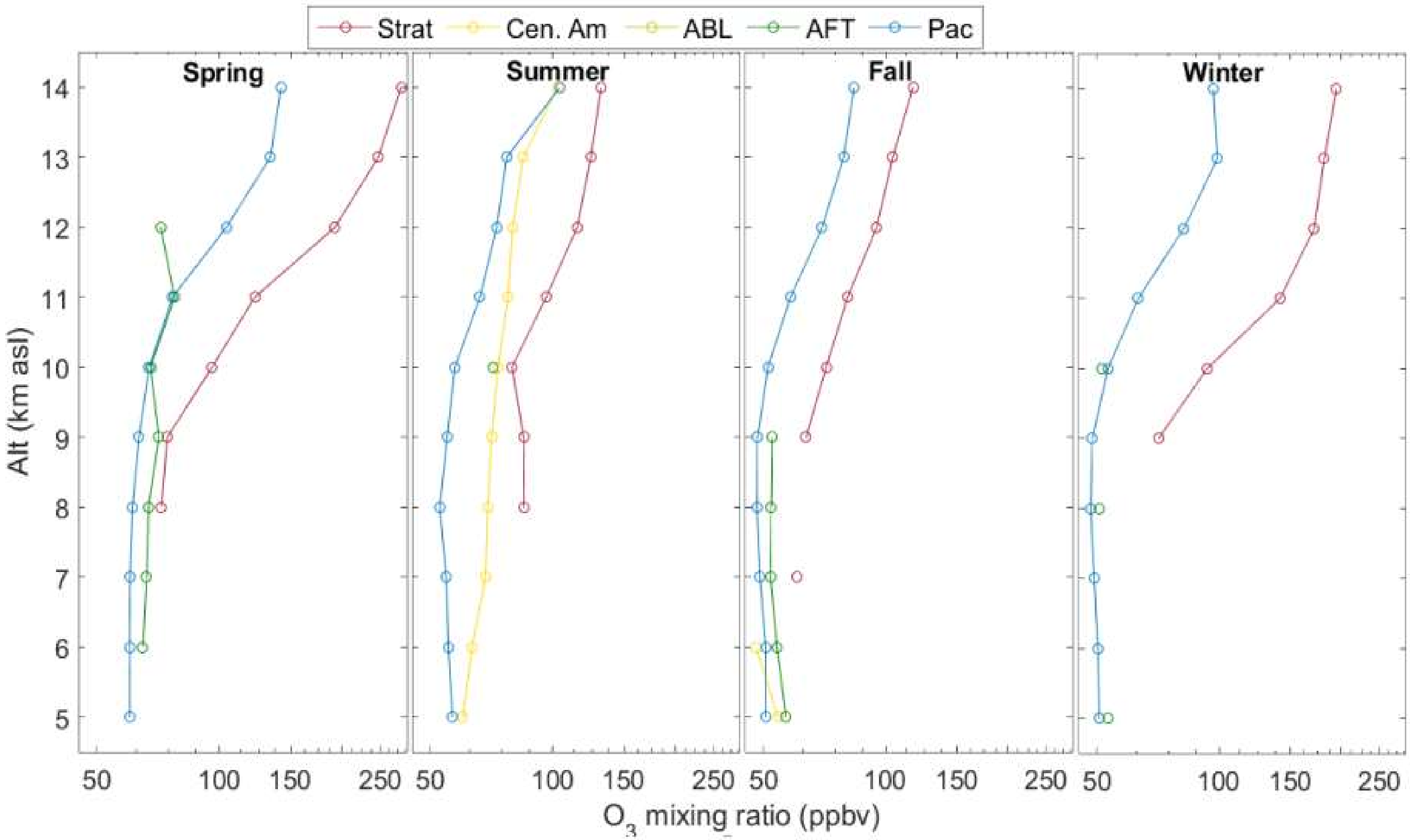




- **Measurements and models indicate the largest O_3 concentrations occurred ~3-6 km above ground level in a very dry air mass near the UAH TOLNet site**

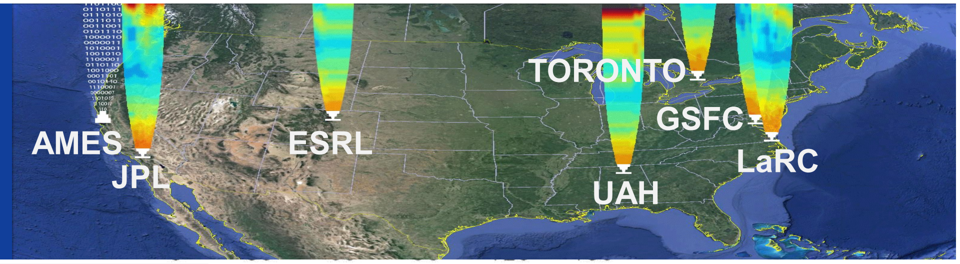
TOLNet/NASA/JPL/TMF: Source attribution by trajectory analyses

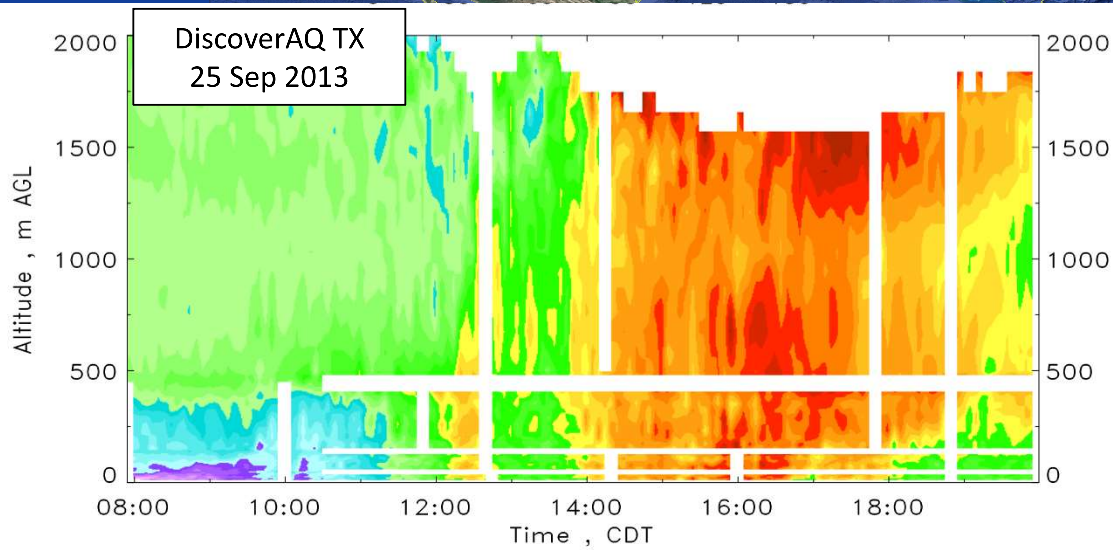




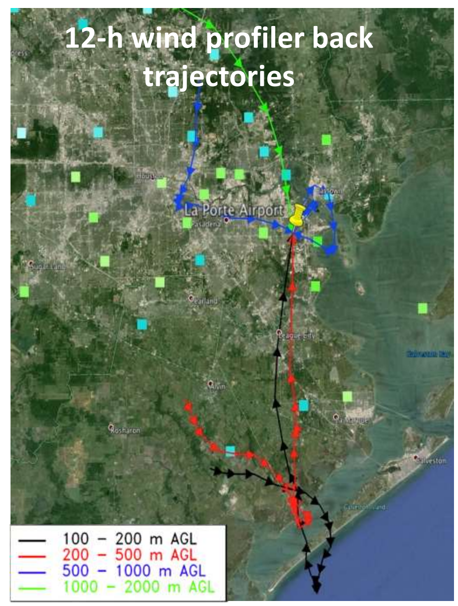
- 5 main source regions for air masses impacting TMF: stratosphere, Asian boundary layer (ABL), free-troposphere above Asia (AFT), Central America, and Pacific Ocean
- Larger O_3 values associated to stratospheric air masses regardless of season
- O_3 enhanced values in summer observed for Central American air masses (related to lightning-induced local production during the North American monsoon)

TOLNet/NOAA/ESRL TOPAZ Land-sea breeze affects Houston ozone levels

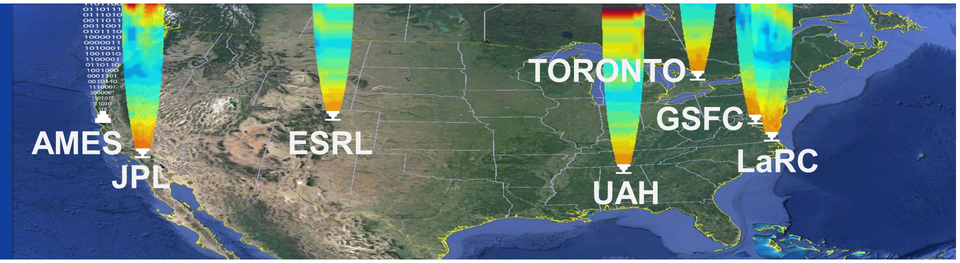




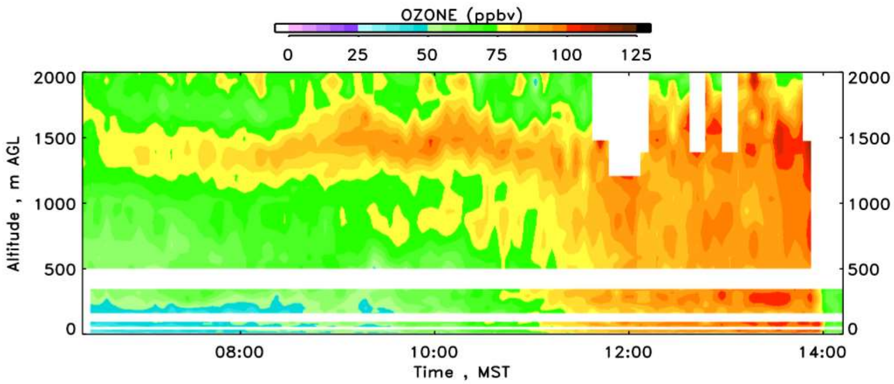
- Light winds and recirculation of pollutants by the land-sea breeze led to very high afternoon O_3 concentrations.
- Titration of O_3 in the shallow morning boundary layer was followed by a quick increase in O_3 due to photochemical production.
- A rapid rise of the boundary layer around midday caused a temporary drop in O_3 levels as cleaner air from aloft was mixed down.
- In the evening, the sea breeze brought in lower-O_3 air in the lowest few hundred m AGL, leaving a "dirty" residual layer aloft.

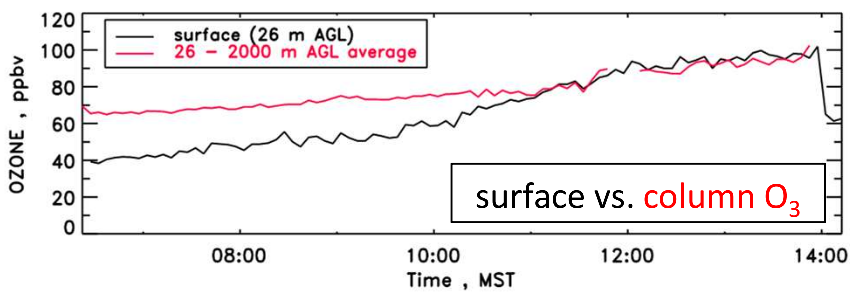


TOLNet/NOAA/ESRL TOPAZ Evaluation of satellite-derived surface ozone

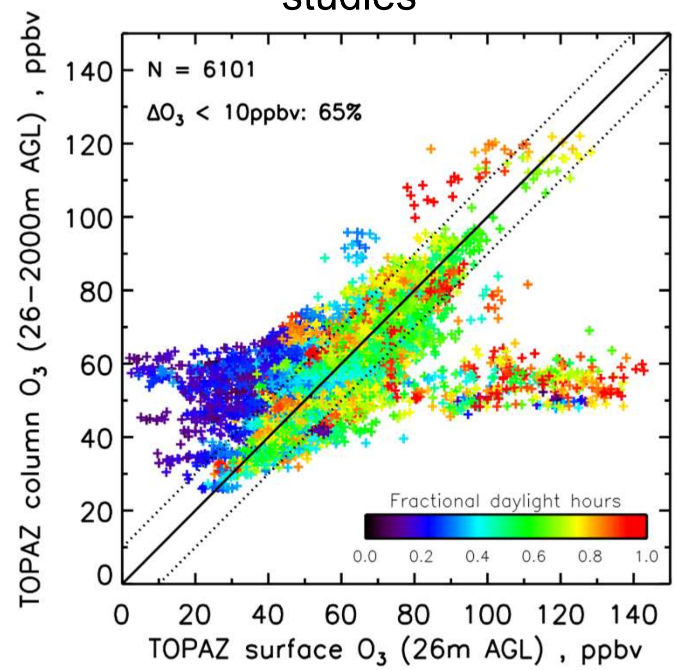


DiscoverAQ Colorado: 29 Jul 2014





Surface vs column O_3: 4 field studies

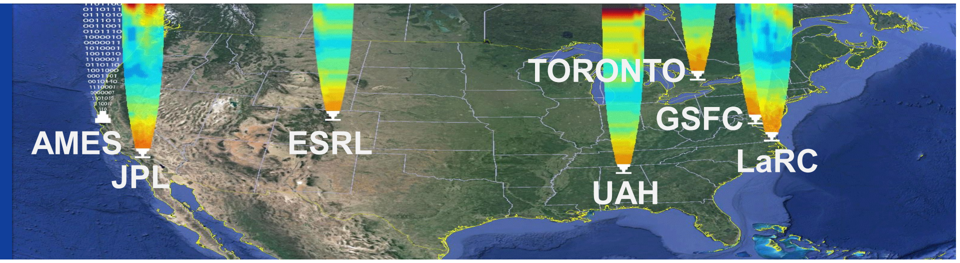


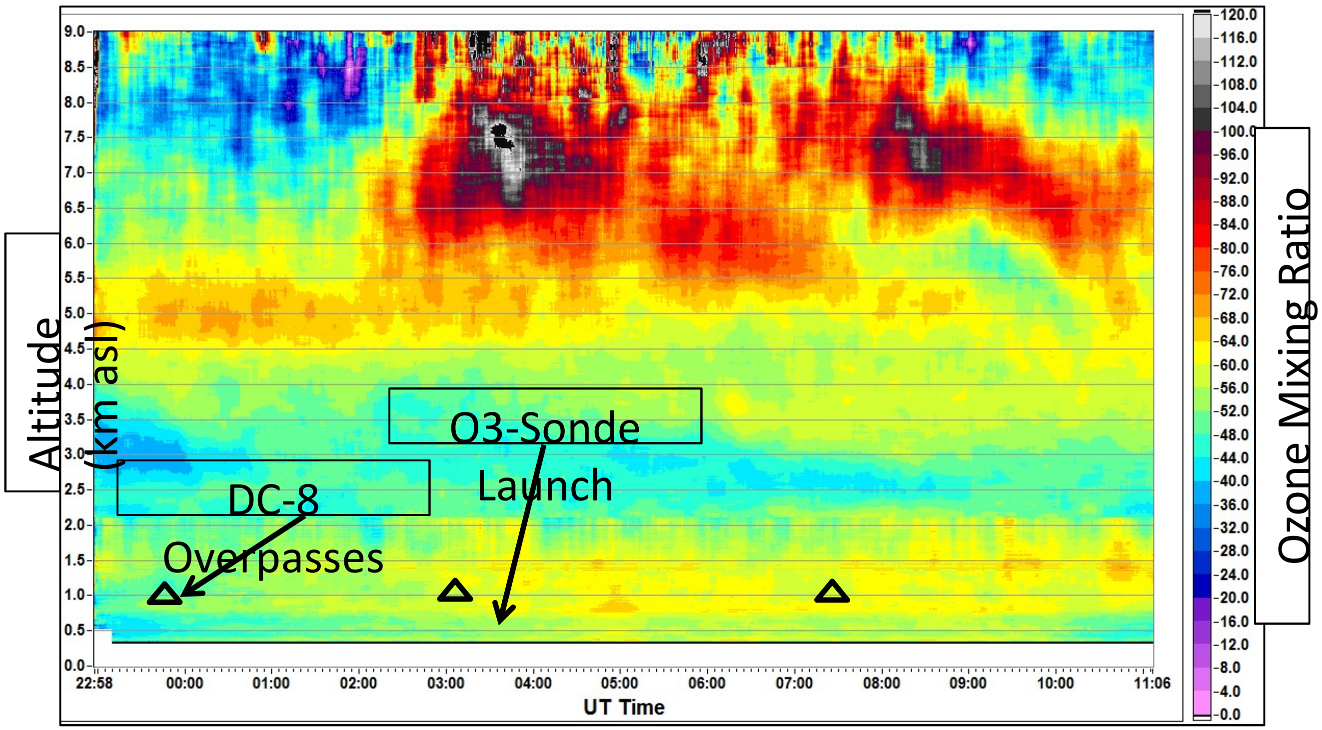
- TOPAZ lidar measurements close to the surface and surface-to-2km lidar O_3 column averages from four different field studies were compared to assess the ability of future satellites (e.g. TEMPO) to measure surface O_3 by way of lower-atmosphere column observations.
- Column and surface O_3 observations typically agree from mid-day through the afternoon, when the boundary layer is usually well mixed. Biases occur when significant O_3 gradients are present in the lower troposphere, due to, e.g., a shallow mixed layer or low-level advection of different air masses by thunderstorm outflows or the sea breeze.

TOLNet

GSFC TROPOZ DIAL at

Taehwa, Korea 4 May, 2016





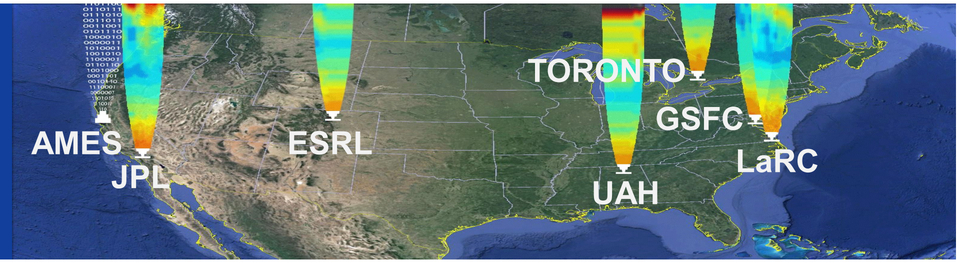
TOLNet/TROPOZ measurements at the Taehwa site in support of all aircraft overpasses (black triangle denotes DC-8). Following a deep cyclonic depression and jet stream trough over the Korean Peninsula, we observed stratospheric air in the free troposphere. Ozone remained near 40-50 ppbv at the surface for nearly the entire day. O3-sonde was launched near 03:30 UT to further characterize the stratospheric intrusion. Balloon profile indicated ozone near 200 ppb at 8 km, coupled with very dry and cold air conditions.

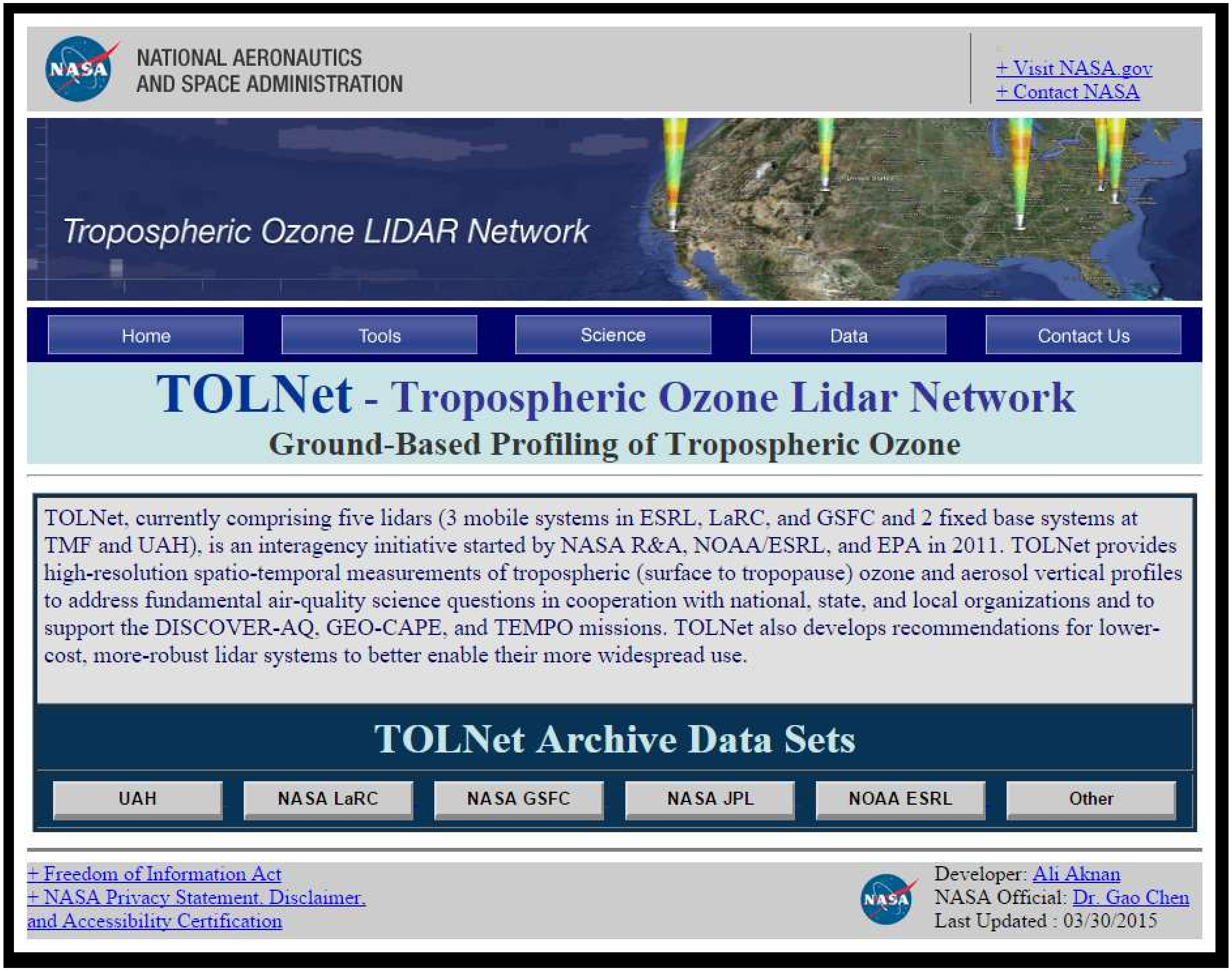
TOLNet website and DOI Landing Page

http://www-air.larc.nasa.gov/missions/TOLNet/

10.5067/Lidar/Ozone/TOLNet

Or Google 'TOLNet'





NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

+ Visit NASA.gov
+ Contact NASA

Tropospheric Ozone LIDAR Network

Home | Tools | Science | Data | Contact Us

TOLNet - Tropospheric Ozone Lidar Network

Ground-Based Profiling of Tropospheric Ozone

TOLNet, currently comprising five lidars (3 mobile systems in ESRL, LaRC, and GSFC and 2 fixed base systems at TMF and UAH), is an interagency initiative started by NASA R&A, NOAA/ESRL, and EPA in 2011. TOLNet provides high-resolution spatio-temporal measurements of tropospheric (surface to tropopause) ozone and aerosol vertical profiles to address fundamental air-quality science questions in cooperation with national, state, and local organizations and to support the DISCOVER-AQ, GEO-CAPE, and TEMPO missions. TOLNet also develops recommendations for lower-cost, more-robust lidar systems to better enable their more widespread use.

TOLNet Archive Data Sets

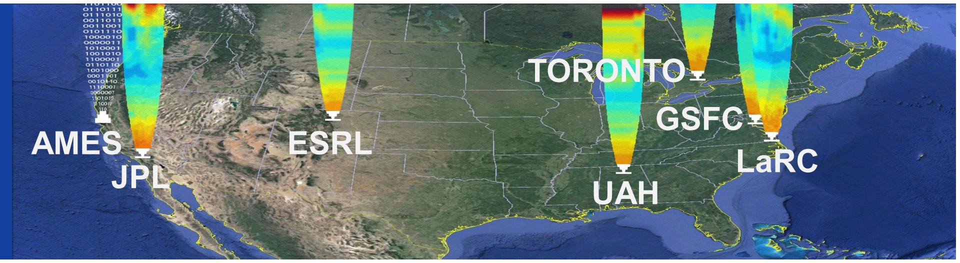
UAH | NASA LaRC | NASA GSFC | NASA JPL | NOAA ESRL | Other

+ Freedom of Information Act
+ NASA Privacy Statement, Disclaimer, and Accessibility Certification

Developer: Ali Aknan
NASA Official: Dr. Gao Chen
Last Updated : 03/30/2015

TOLNet

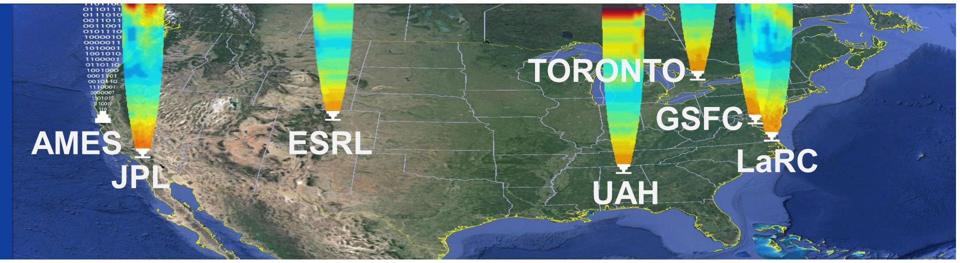
Conclusions



- TOLNet provides high-resolution lidar data at multiple stations to modeling and satellite teams for validating and improving the fidelity of tropospheric ozone measurements by NASA's next-generation geostationary instruments.
- TOLNet lidars agree with ozonesonde free flights and tether flights, with CRDS on the BAO carriage, and with each other to between 1-10% over a wide variety of conditions.
- Analyses of lidar data allow understanding of several processes including smoke transport, PBL growth, entrainment, stratospheric-tropospheric exchange, and laminae morphology.
- Knowledge of the continuous vertical distribution of ozone is essential for understanding the apportionment between local and regional sources and processes.
- TOLNet seeks partnerships with air-quality agencies and practitioners for research and evaluation.

TOLNet

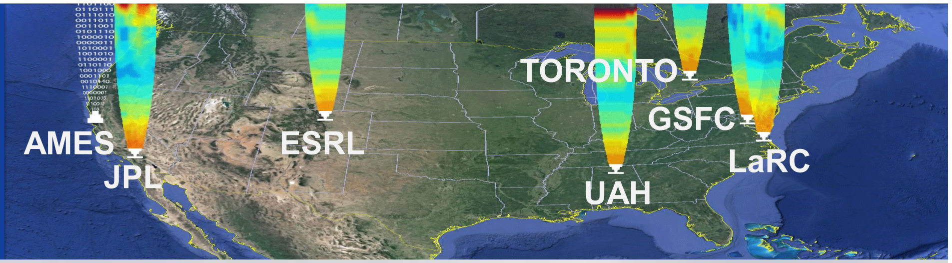
The way forward: Plans and aspirations



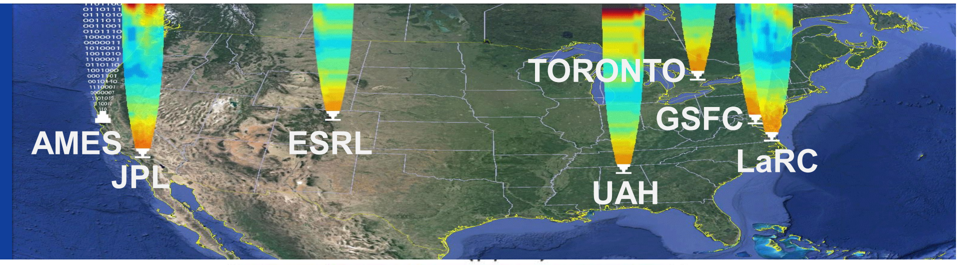
- Maintain routine observations of high-accuracy, high spatio-temporal resolution tropospheric ozone distributions.
- Design and execute campaigns to address specific needs (e.g., KORUS 2016, CARB/SJV summer 2016, JPL/TMF summer 2016).
- Foster partnerships with international, federal, state, local, and tribal air-quality and space agencies to provide data for process studies, exceptional-event attribution, satellite validation and assimilation, and eventually, forecasting.
- Pursue technology avenues toward autonomous, affordable instrumentation.
- Integrate TOLNet ozone and aerosol measuring capabilities with other profiling networks (e.g., MPLnet, Aeronet, NWS wind profilers, ozone and radio sondes) and TEMPO hourly geostationary measurements for a comprehensive 4-D measurement capability.

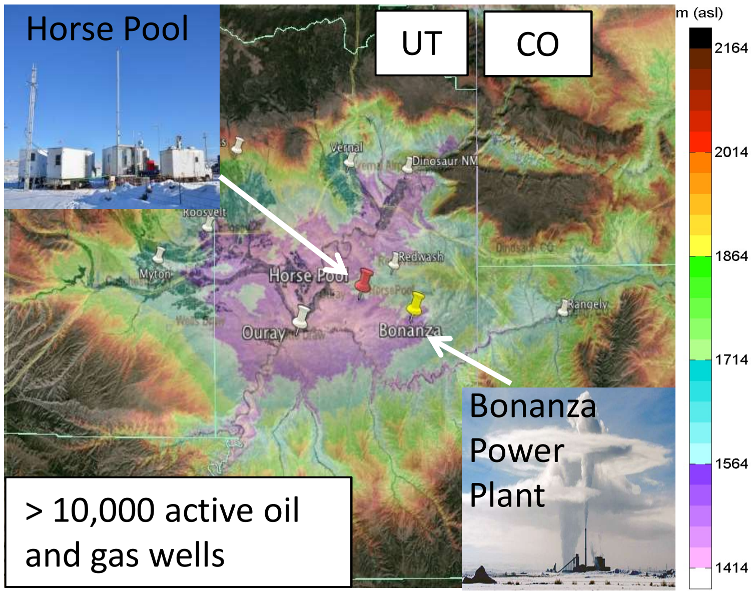
Back up

2[nd] Annual TOLNet Meeting 2015 at NOAA/ESRL Boulder, CO

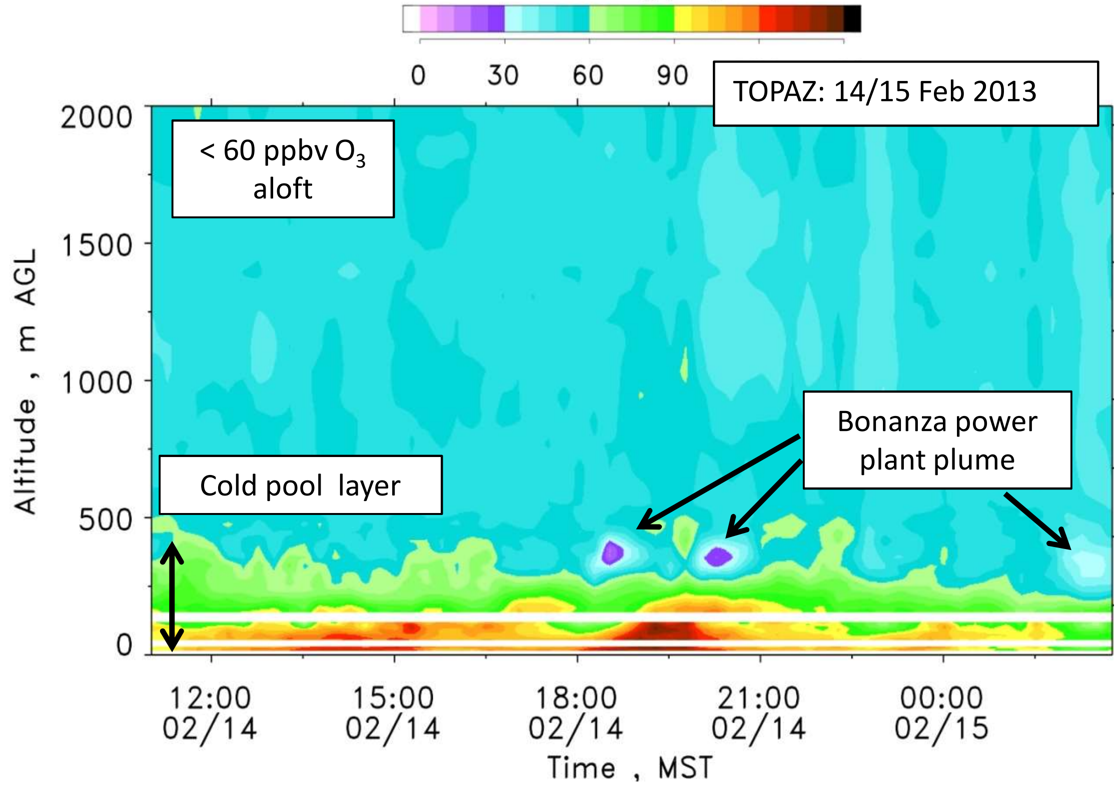


TOLNet/NOAA/ESRL TOPAZ
High wintertime ozone in an oil & gas region



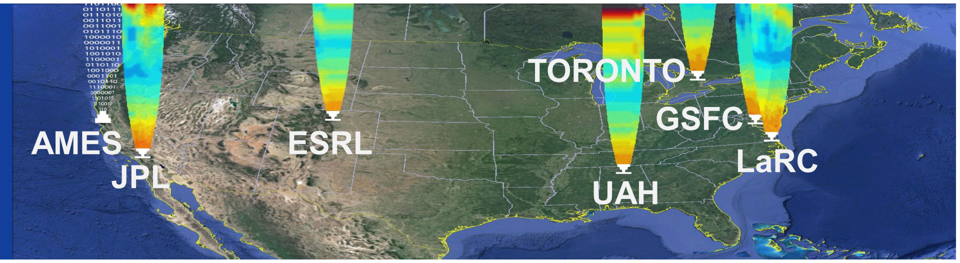


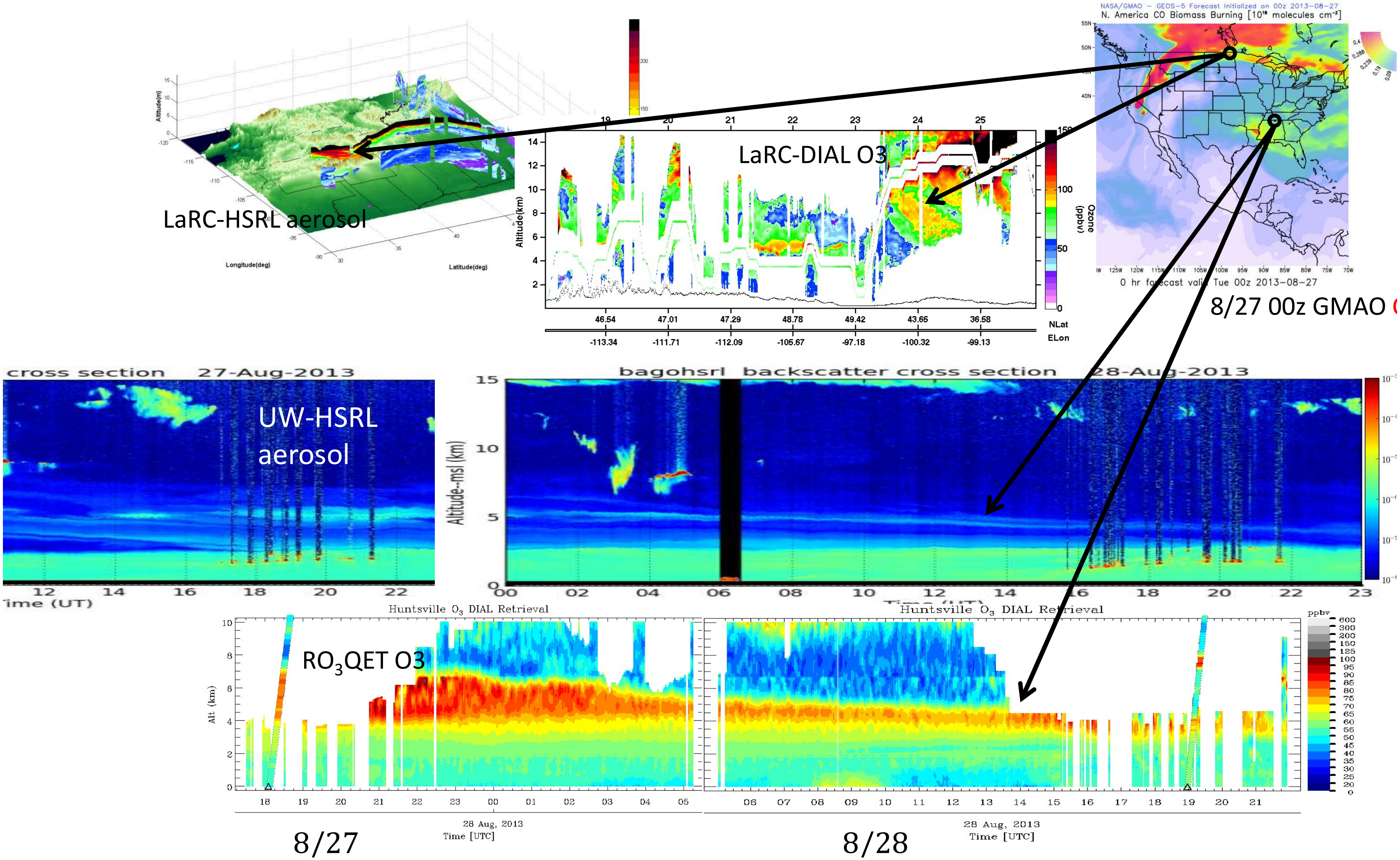
Uintah Basin, UT



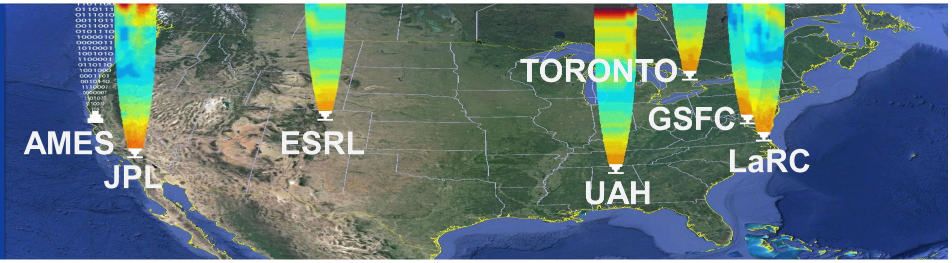
- High O_3 concentrations were confined to a 400-m deep cold pool layer.
- Bonanza power plant emissions did not mix down to the surface.
- No indication of long-range or stratosphere-to-troposphere transport of elevated O_3.
- Local emissions from oil & gas extraction are the main driver of high O_3 concentrations.

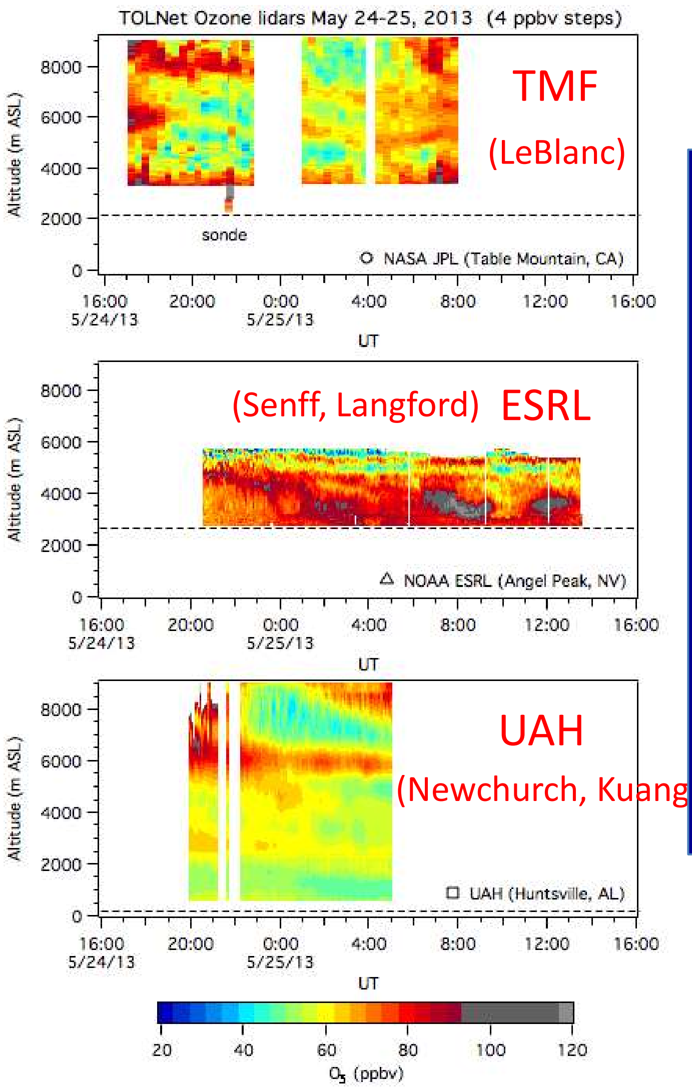
TOLNet/UAH RO$_3$QET: CA wildfire detection by airborne LaRC/DIAL&HSRL, RO$_3$QET, and UW-HSRL over Huntsville





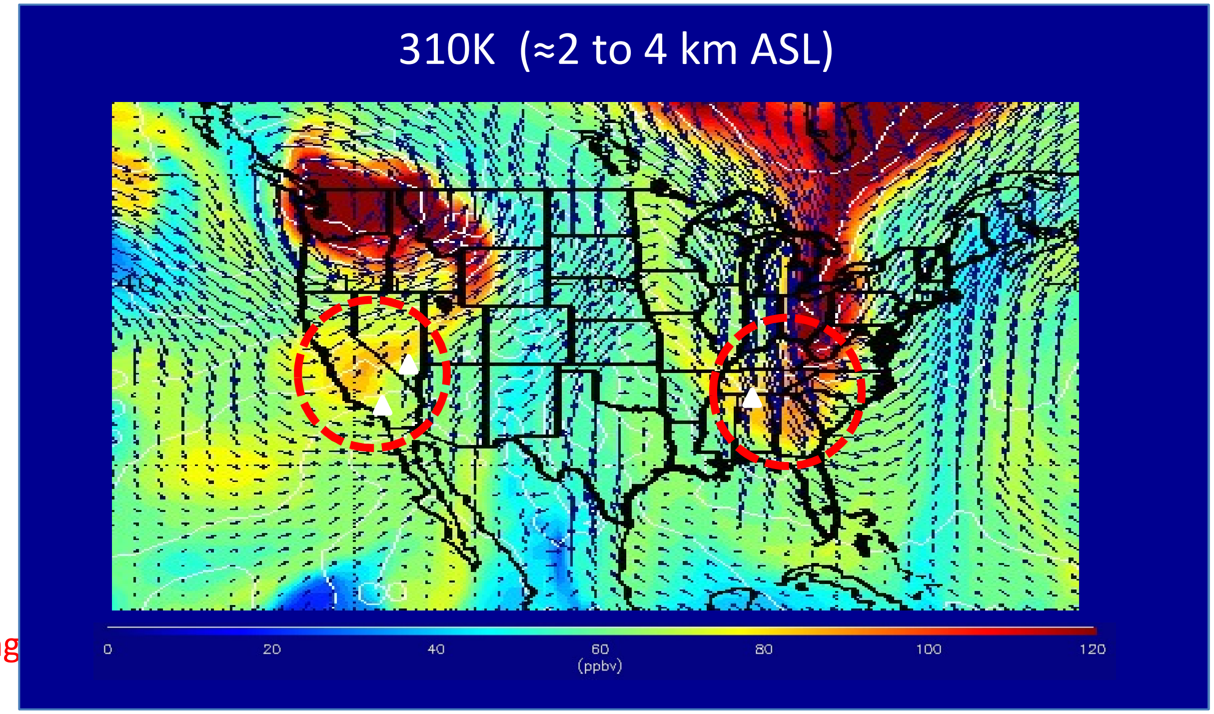
TMF, TOPAZ, & RO_3QET measure two continental-scale stratospheric folds





Lidar measurements

Note the ESRL obs was made at Las Vegas.



May 24, 2013 12UT RAQMS 310-K ozone
Brad Pierce (NOAA/NESDIS)

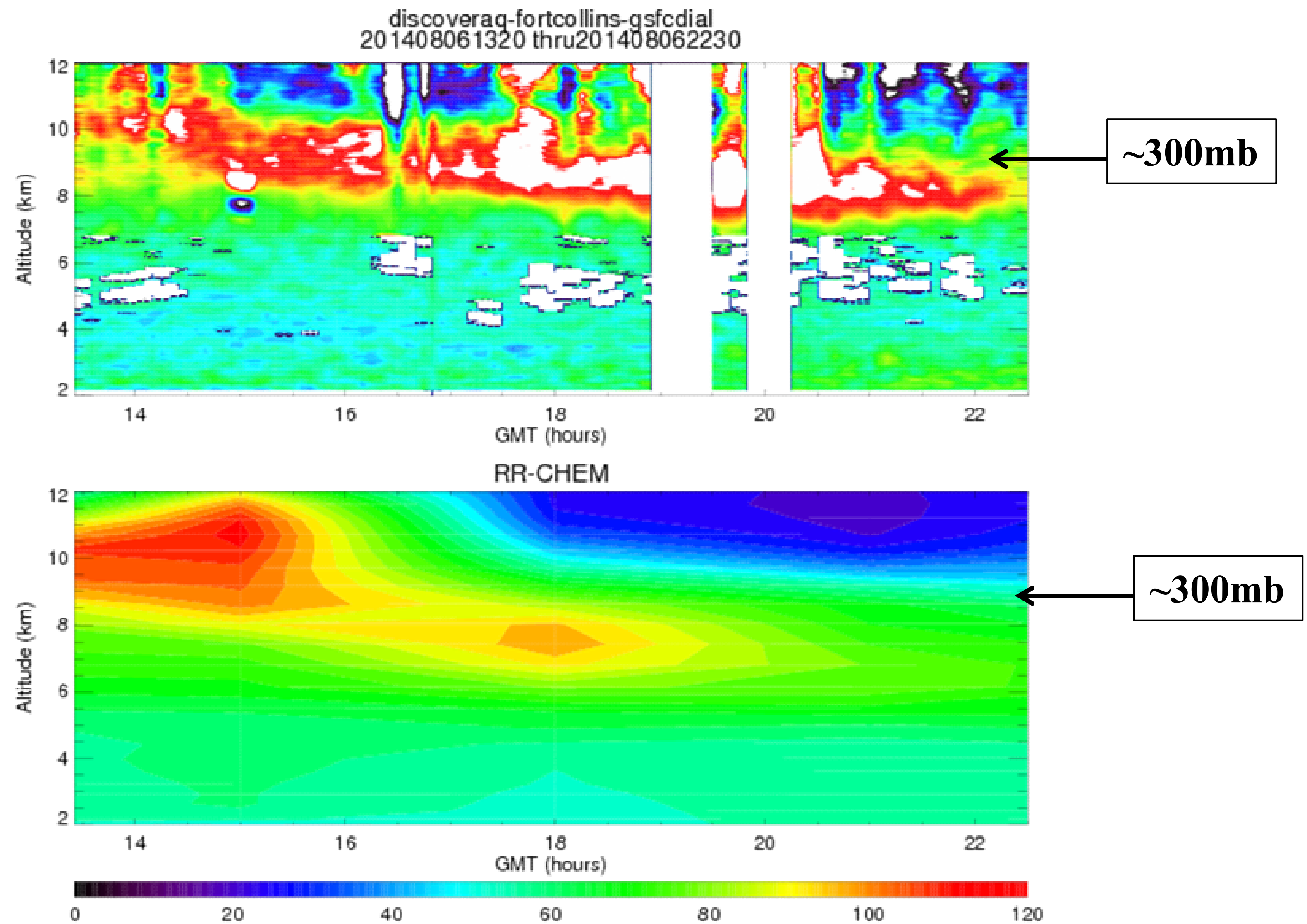
Understanding Background Ozone over the Continental US: A Global Ozone Assimilation Perspective

Brad Pierce
NOAA/NESDIS

Collaborators:
RAQMS (Todd Schaack and Allen Lenzen, UW-Madison/SSEC)
RR-Chem (Georg Grell and Steve Peckham, NOAA/ESRL),
AJAX measurements (Emma Yates and Laura Iraci, NASA Ames)
EPA SI Working Group (Gail Tonnesen, US EPA, and Patrick Reddy, CDPHE)
Mount Bachelor Observatory (Dan Jaffe, Pao Baylon, Univerisity of Washington)
TOLNet (Thierry Leblanc, JPL, Tom Mcgee, GSFC, John Sullivan UMBC)

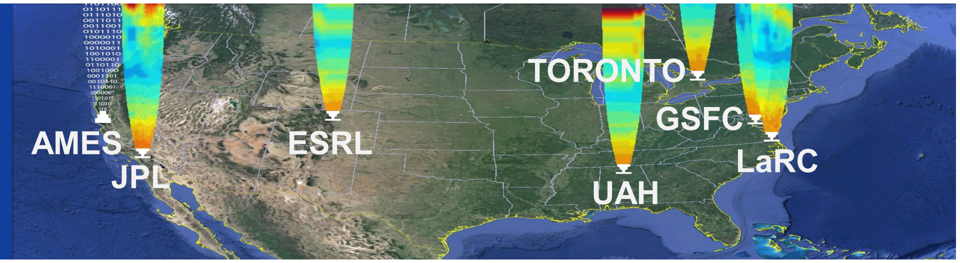
Second Annual Tropospheric Ozone Lidar Network (TOLNet) Working Group Meeting, June 16-18, 2015 Boulder, CO

RR-CHEM vs TOLNet Ft. Collins August 6, 2014



TOLNet GSFC Tropospheric Ozone Lidar (TROPOZ) (Thomas J. McGee, NASA/GSFC, John Sullivan, UMBC/JCET)

Brad Pierce/NOAA/NESDIS message to TOLNet 2015

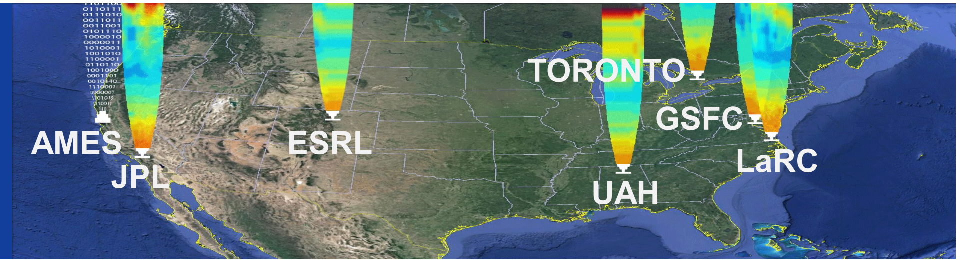


- **Intercontinental Pollution (Asian anthropogenic and biomass burning) and Stratospheric Intrusions can lead to significant ozone enhancements off the west coast of the US during Spring and early summer (March-July)**

- **Long-term oscillations such as the Pacific Decadal Oscillation can lead to significant variations in tropospheric ozone columns over the Eastern Pacific which can lead to systematic changes in surface ozone over the Western US**

- **TOLNet observations show that while global ozone analyses are able to capture interannual variations in tropospheric ozone columns, daily variations in background ozone are still underestimated, even within nested global/regional forecasting systems**

David Parrish/ESRL: Estimating Baseline Contributions to Surface Ozone in California's Central Valley



- Surface O_3 in North Sacramento Valley enhanced due to inflow of higher altitude air
- San Joaquin Valley surface O_3 evolution consistent with similar inflow into that valley as well
- TOLNet observations could provide direct evidence for that inflow

Implication:

Higher O_3 in San Joaquin Valley than South Coast Air Basin means that the Nation's O_3 pollution problem is no longer predominately a large city problem; it now can be worse in rural areas!