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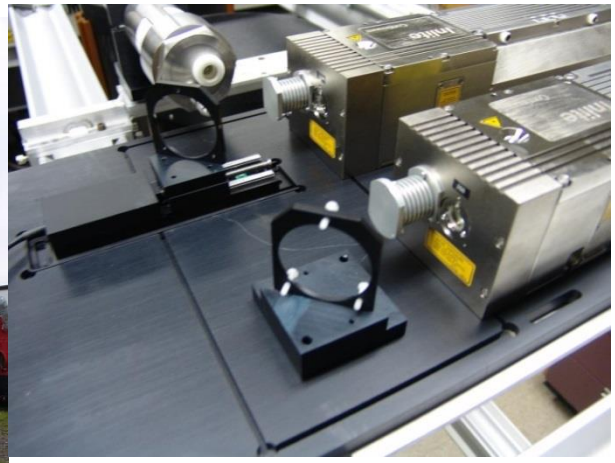
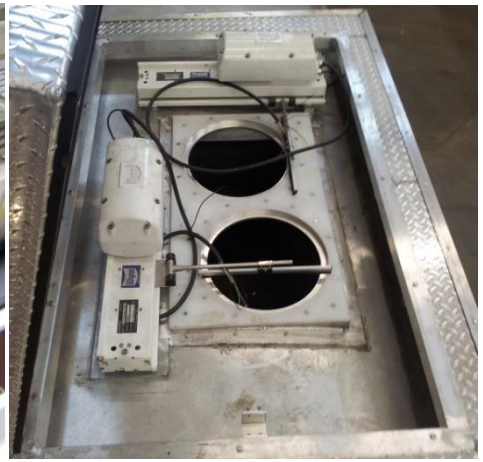
Canada

First Year Operation of an Autonomous Tropospheric Ozone, Water Vapor, Aerosol Lidar Facility in Northern Alberta





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Environment and Climate Change Canada (ECCC)
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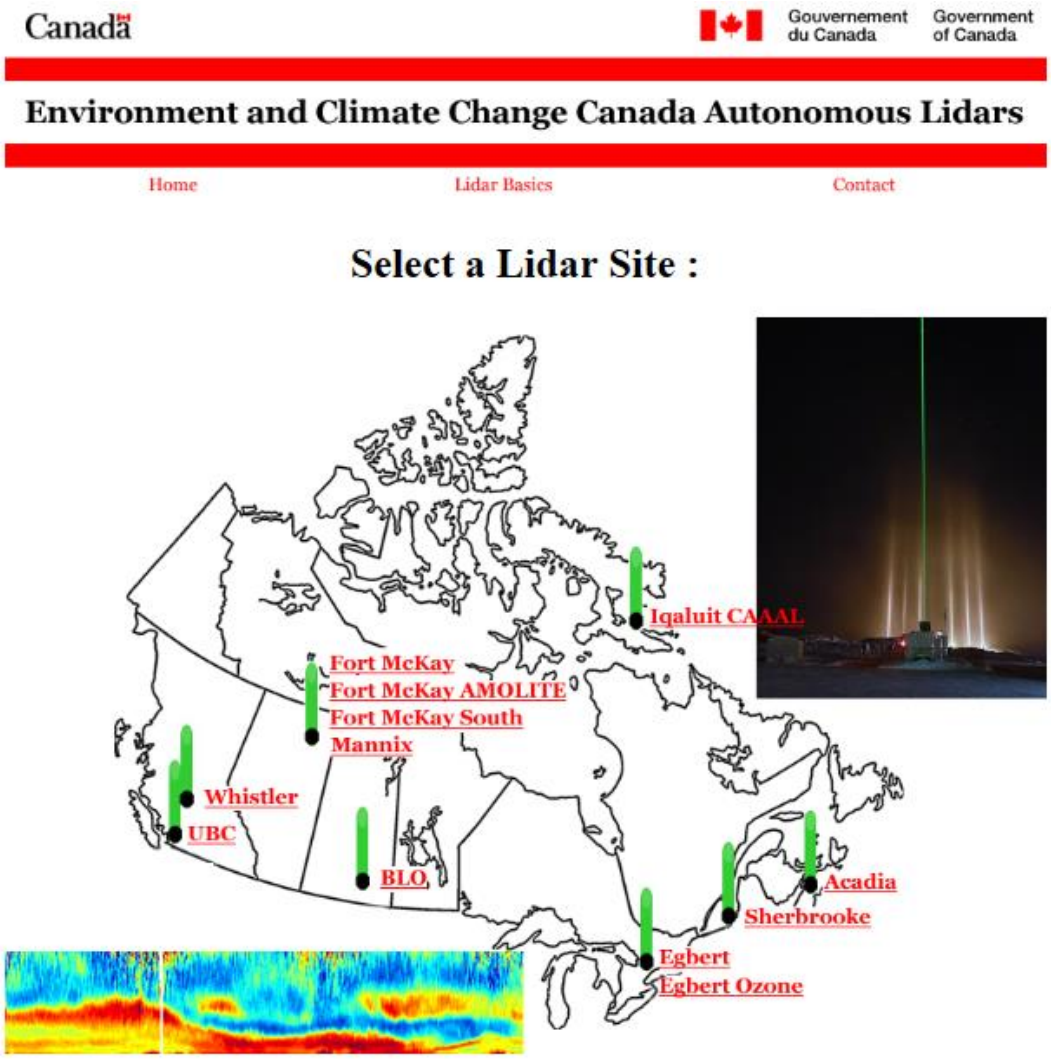
Overview

- Motivation – Why build it??
- Instrument Design
  - Fully autonomous operation – near real-time upload to website
  - Mobile Platform
  - Aerosol Backscatter LIDAR
  - Tropospheric Ozone DIAL
  - Night time water vapour
- Testing and Validation Results
- First year's results from field deployment
- Summary and Future Work

Ozone and Aerosols

- Tropospheric ozone and aerosols (PM10 and PM2.5) are important atmospheric constituents in low altitude pollution affecting human health and vegetation
- Ozone is photo-chemically active with nitrogen oxides – diurnal variations of photochemical smog
- Aerosols contribute to the radiative budget, tracer for pollution transport, complex mixing, visibility and cloud formation
- Improve AQ forecast and diagnostic models

ECCC Autonomous Lidars



Autonomous Lidar Operation

- Climate Control
  - even distribution throughout trailer
  - handle -40 to + 40 C
  - need feedback (outside temp, inside temp)
  - must be able to control via software/hardware interface
- Simple instrument design
  - optical design
  - optical layout
  - single Raman cell
  - well tested hardware

Autonomous Lidar Operation

- Operational consideration
  - permission to operate laser outdoors (Transport Canada, FAA)
  - power, internet
  - hatch, rain gauge
  - website to upload data in real time
  - website to monitor system health
  - emailer for system issues
  - PDU – “save your life”
  - keep the optics clean
  - remote alignment capability
  - safety issues inside and outside the trailer

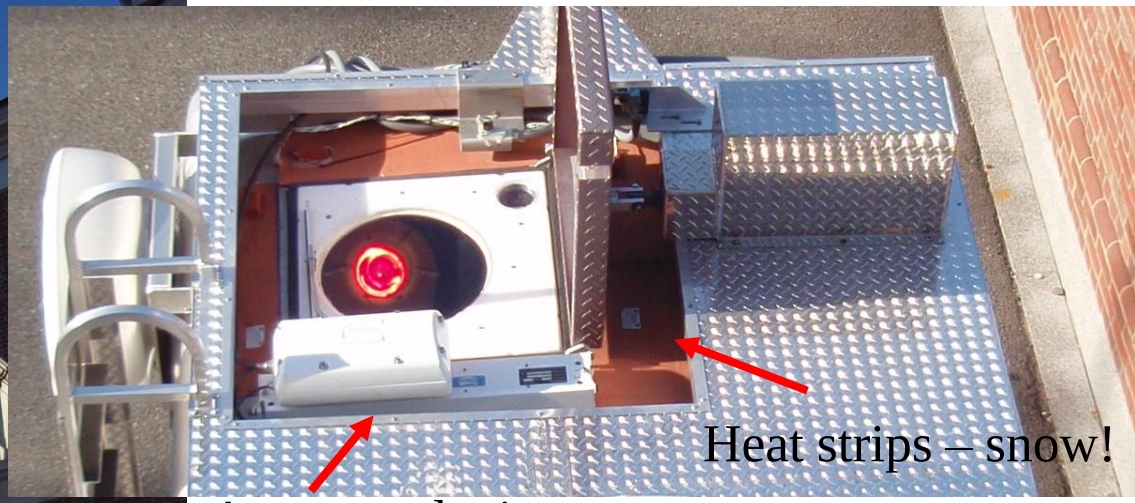
Autonomous Lidar Operation

- Redundancy
  - two radars
  - two lasers or more robust laser
  - back up computers
  - back up hard drives
- Computer Control – “artificial intelligence”
  - sophisticated software control -
  - automatic reboot of some systems etc

Other TOLNet lidars are implementing these ideas

eg. Thierry/Fernando @ JPL TMF lidar

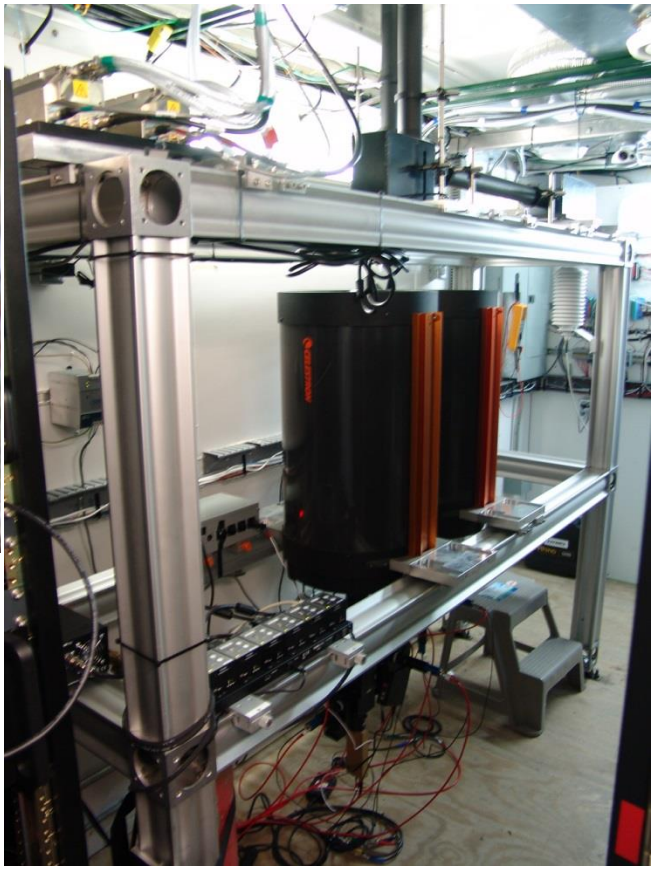
Autonomous LIDAR challenges



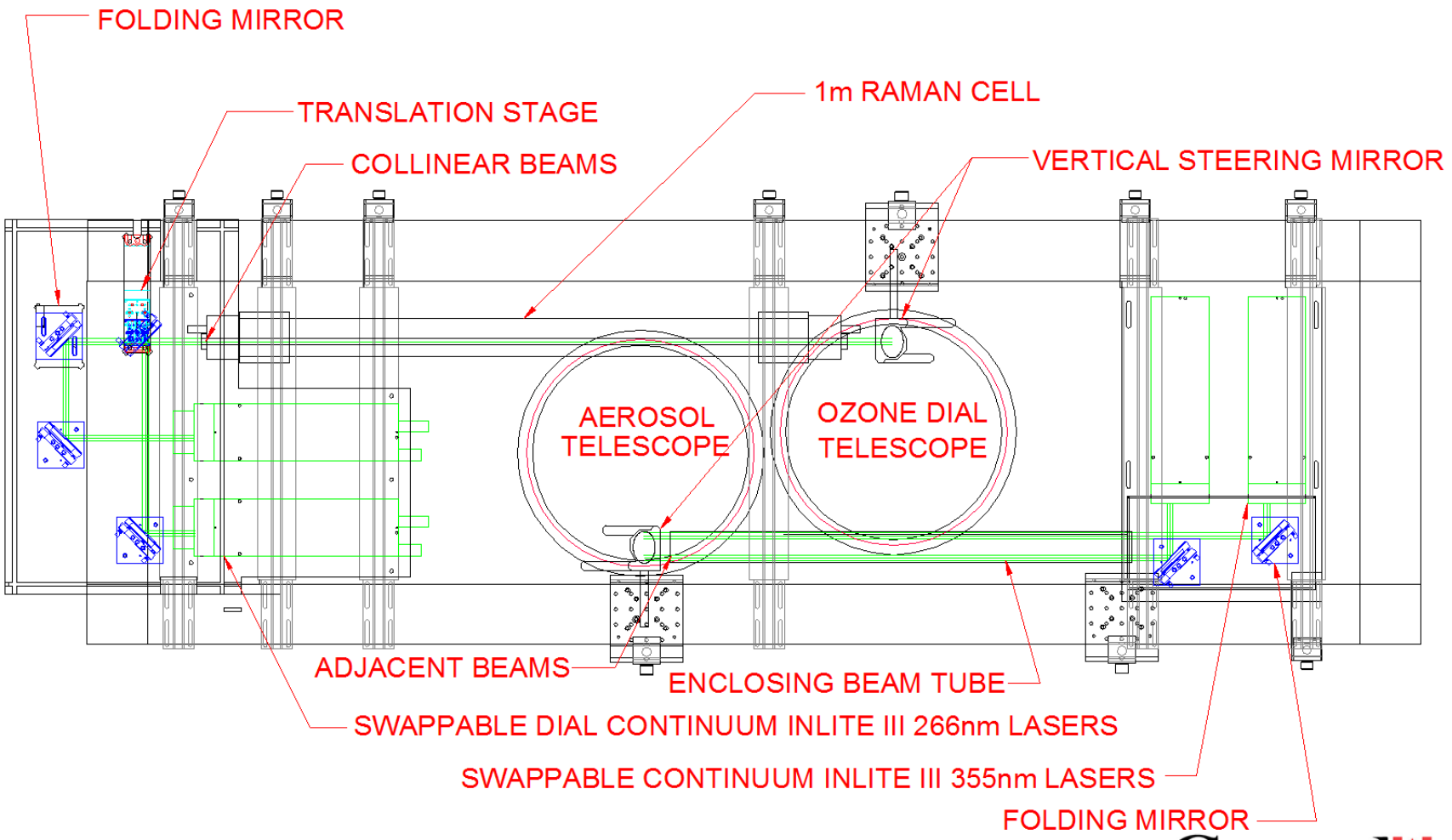
Remote alignment

Autonomous Mobile Ozone Lidar Instrument for Tropospheric Experiments (AMOLITE)

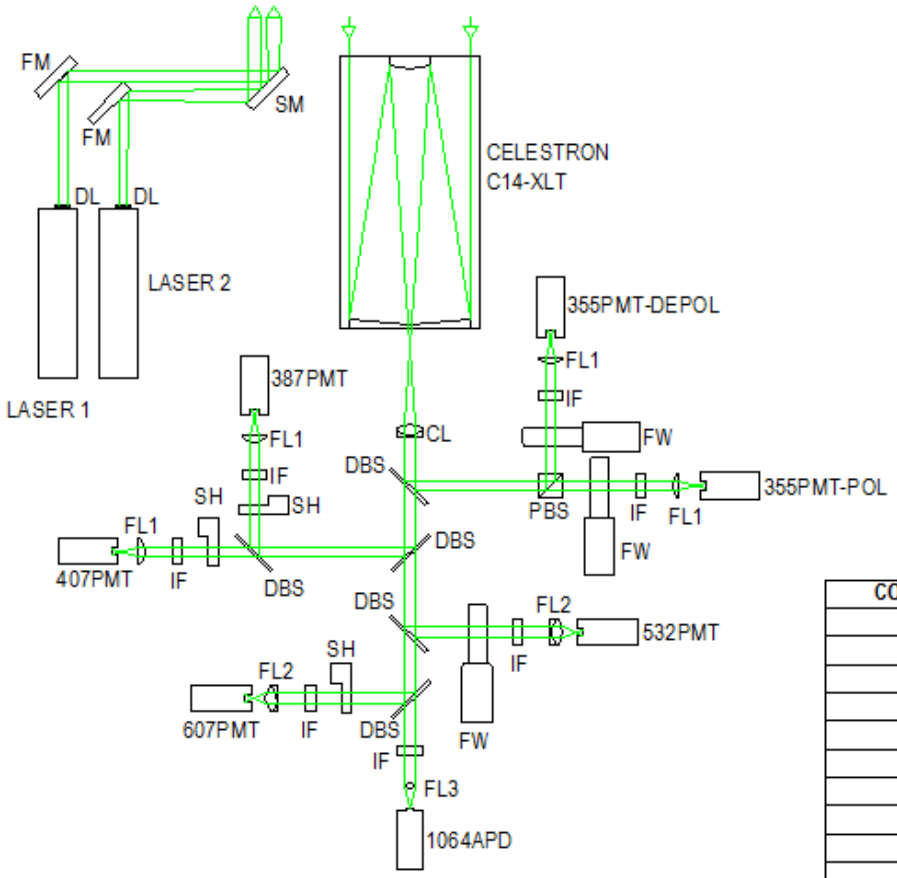
Named after gemstone AMMOLITE that is only found in Canada!



Lidar Optics Bench Layout

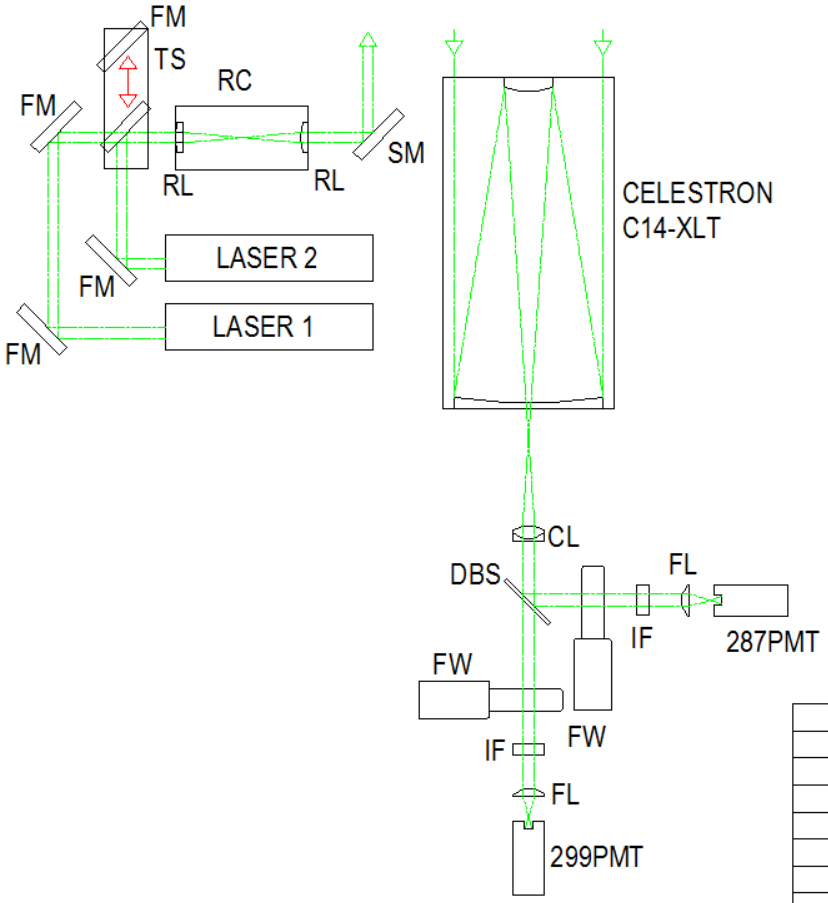


Optical Layout– Aerosol Lidar



COMPONENT	DESCRIPTION
DL	DIVERGING LENS
FM	FOLDING MIRROR
SM	STEERING MIRROR
CL	ACHROMAT COLLIMATING LENS
DBS	DICHROIC BEAM-SPLITTER
PBS	POLARIZING BEAM-SPLITTER
FW	FILTER WHEEL
IF	INTERFERENCE FILTER
FL1	PLANO-CONVEX FOCUS LENS
PMT	PHOTOMULTIPLIER TUBE
FL2	ACHROMAT FOCUS LENS
SH	SHUTTER
FL3	BI-CONVEX FOCUS LENS
APD	AVALANCHE PHOTO-DIODE

Optical Layout – Ozone DiAL



COMPONENT	DESCRIPTION
FM	FOLDING MIRROR
TS	TRANSLATION STAGE
RC	RAMAN CELL
RL	PLANO-CONVEX RAMAN LENS
SM	STEERING MIRROR
CL	ACHROMAT COLLIMATING LENS
DBS	DICHROIC BEAM-SPLITTER
FW	FILTER WHEEL
IF	INTERFERENCE FILTER
FL	PLANO-CONVEX FOCUS LENS
PMT	PHOTOMULTIPLIER TUBE

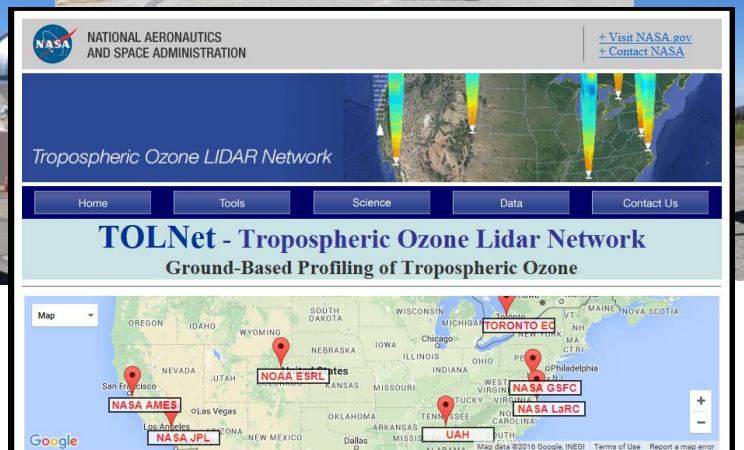
TOLNet SCOOP (Southern California Ozone Observation Project)

NOAA (TOPAZ)

HOST: Table Mountain Facility

NASA LaRC (LMOL)

NASA GSFC (TROPOZ)



ECCC (AMOLITE)

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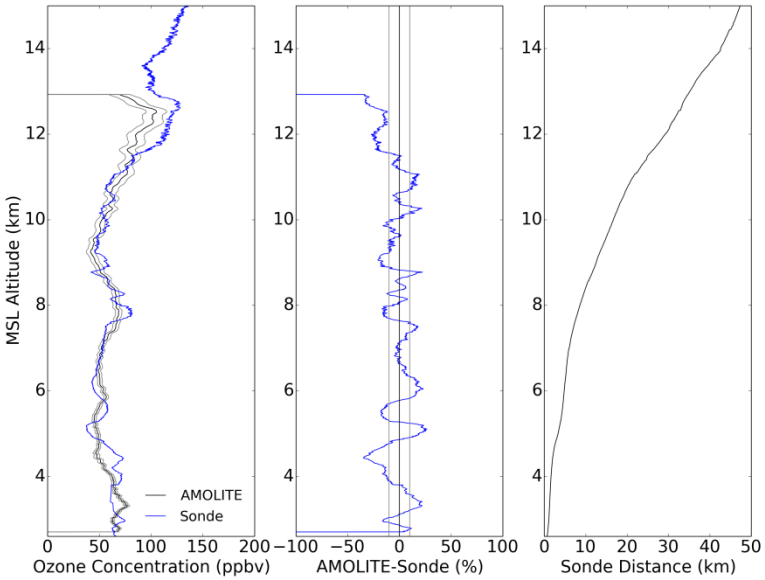
Ozone sonde launch schedule

- Several ozone sondes launched at various times of the day
- Tethered sonde was also operated in first 100m

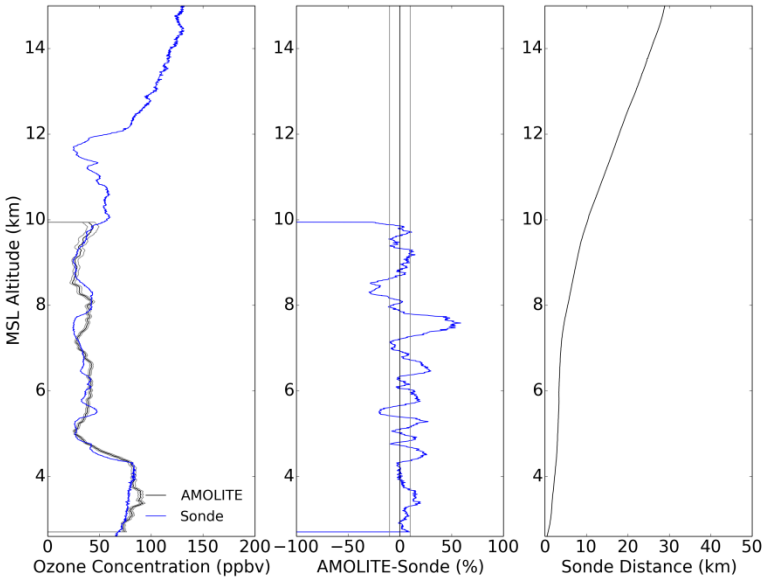
Ozonesonde Launches		
Sonde #	Sonde Date	Sonde Time (UTC)
73	10-Aug-16	4:01:45
75	11-Aug-16	3:01:48
76	11-Aug-16	20:01:39
77	12-Aug-16	2:01:44
78	12-Aug-16	11:32:15
79	12-Aug-16	14:39:33
80	12-Aug-16	17:33:10
81	13-Aug-16	19:01:40
82	14-Aug-16	0:44:06
83	14-Aug-16	4:15:15
84	15-Aug-16	11:37:38
85	15-Aug-16	15:32:55
86	15-Aug-16	17:42:01
87	15-Aug-16	21:47:21
88	16-Aug-16	1:02:18
89	16-Aug-16	3:59:47

DIAL Ozone Vs. Ozone Sonde

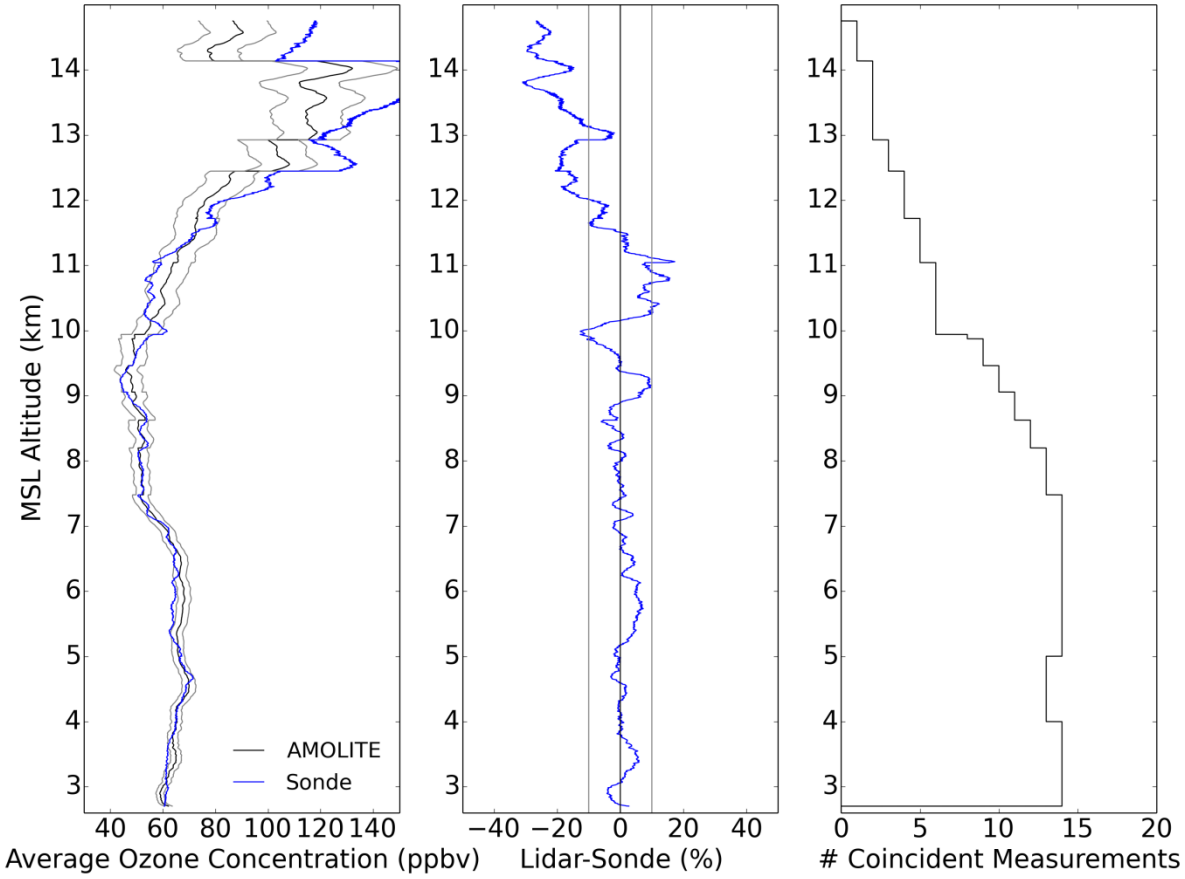
Night time profile



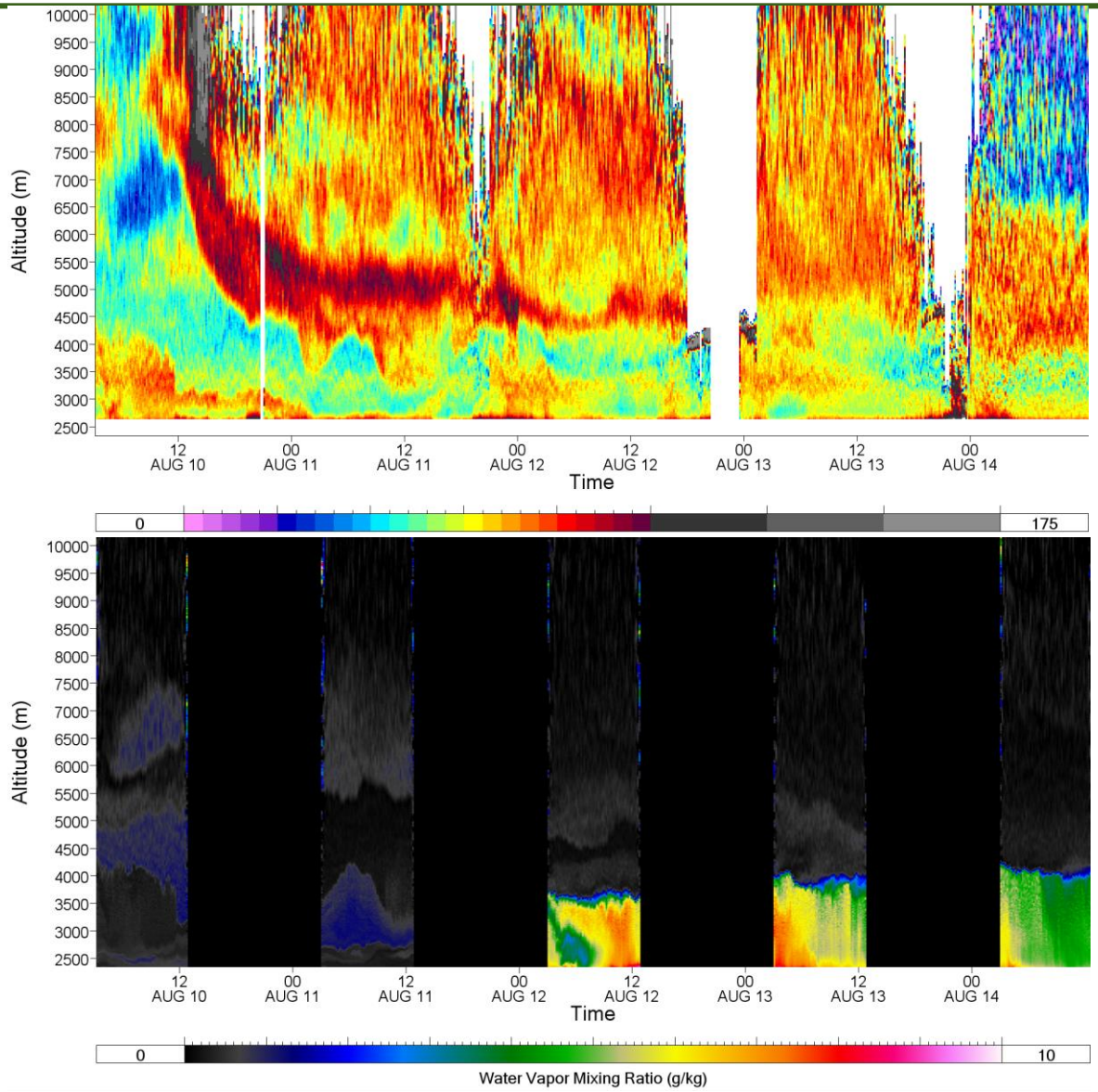
Day time profile



DIAL Ozone Vs. Ozone Sonde – entire campaign average



Stratospheric Intrusion

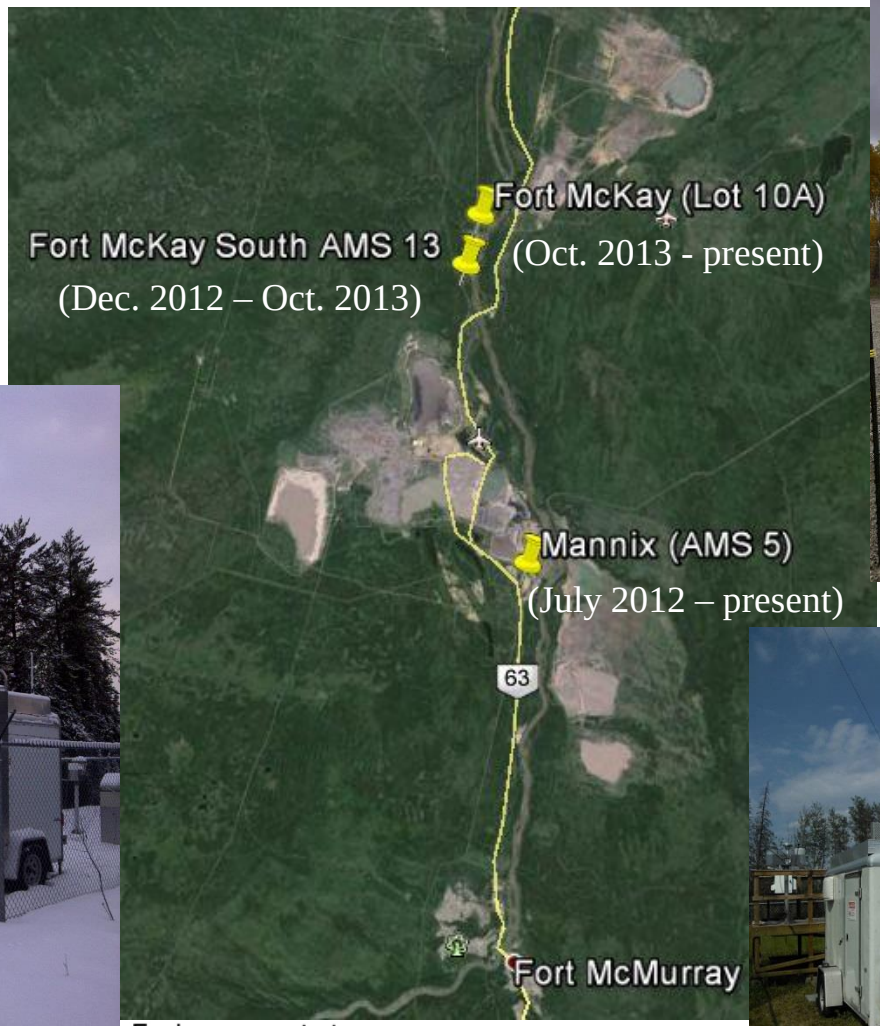


Canada

Deployment to the Oil Sands Region

- Coincident and long-term record for aircraft measurements
  - In-situ chemistry package
  - Winter campaign planned
- Coincident and long-term record for ground measurements
  - Ground-level ozone, NO_x etc
  - CIMEL sunphotometer
  - WIND RAS
- Satellite comparison/validation (eg. TEMPO)
- Environment Canada GEM-MACH Model verification/validation

LIDAR Locations in the OS Region

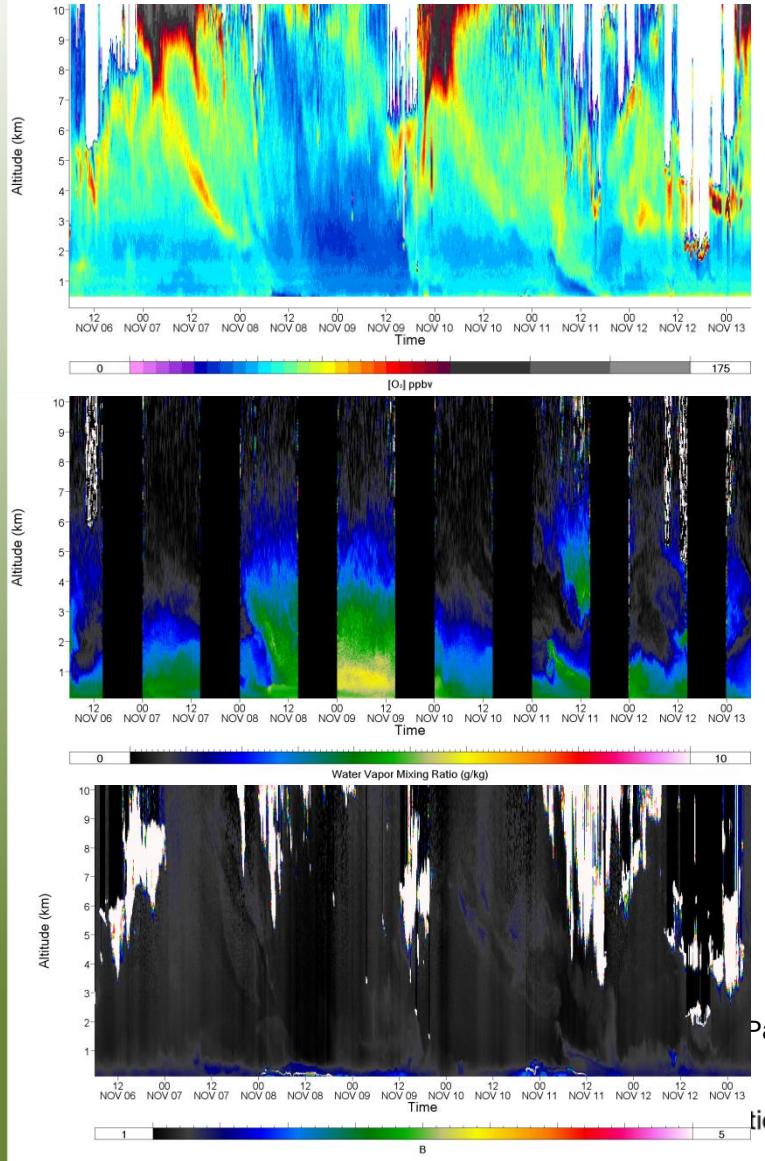


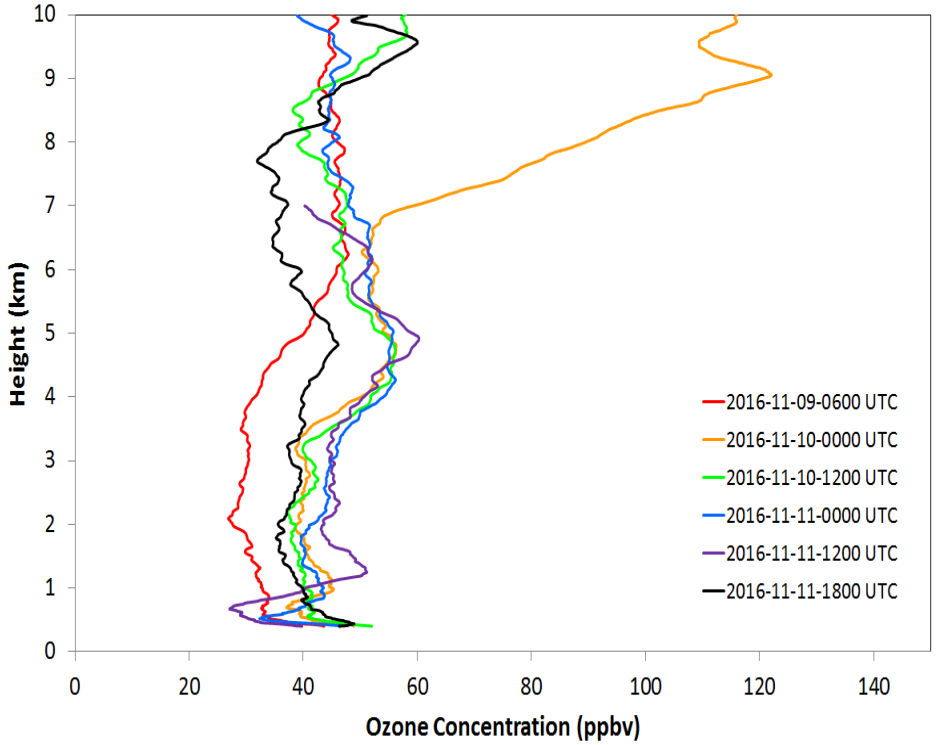
Instrumentation at Fort McKay (Oski Otin) Site

chemistry measurements from CAM1 courtesy of Jeff Brook (ECCC)

Measurement(s)	Instrument
NO_x, O_3, SO_2, H_2S (ppb)	Airpointer with Thermo sensors for pollutants Trace level Thermos r
Temperature (C), pressure (mb), relative humidity (%), wind speed (m/s), wind direction (deg), precip rate/occurrence (mm/hr) and solar radiation (watts/m^2)	CAM-1 (Vaisala and Deka): LIDAR trailer (RM Young, Rotronix and Vaisala) Climatronics Met One
NO, NO2 and NOy (ppb)	Thermo Model 42CTL with a Mo converter
CO (ppb)	Thermo Model 48CTL
Total Sulfur (TS) (ppb)	Thermo Model 43 TL with Thermal Converter (950C) at inlet
CO (ppb), CO_2, and CH_4 (ppm)	Picarro (cavity Ring Down spectrometer)
Benzene, toluene, ethylbenzene xylenes	Syntech (GC/PID at AMS 01
C_5-C_9 Hydrocarbons (ppb) (every 30 min)	Syntech GC/PID
$PM_{2.5}$ (µg/m^3)	5030 Thermo SHARP
Black Carbon (B_{abs} in Mm^{-1})	Droplet Measurement Technologies –Photoacoustic Spectormeter
Particle surface bound polycyclic aromatic hydrocarbons (PAHs), semi-quantitative (ng/m^3)	EcoChem Photo-ionization detector
Particle size distributions 0.03-30 µm (number/cm^3)	GRIMM Dust monitor with Nano Particle counter
Collected samples analyzed for C2-C12 VOCs. (µg/m^3)	Xontech canister sampler
Particle size distributions 0.5-0.30 um and aerodynamic sizing (number/cm3)	TSI Aerodynamic Particle Sizer
Aerosol Optical Depth (AOD) (every 3 min during direct sunlight hours)	CIMEL Sun Photometer
Wind Speed (m/s) and direction (deg), turbulence and temperature (C) vertical profiles up to at least 300 meters (every 15 min)	Radio Acoustic Sounding system (RASS)
Vertical column density SO_2 and NO_2 (Dobson Units) (10 min averages during direct sunlight periods)	Pandora
Vertical aerosol profiles into the upper troposphere (Backscatter ratio)	Light Detection and Ranging (LIDAR)
Vertical ozone profiles from near ground to 7 km	DIfferential Absorption LIDAR (DIAL)

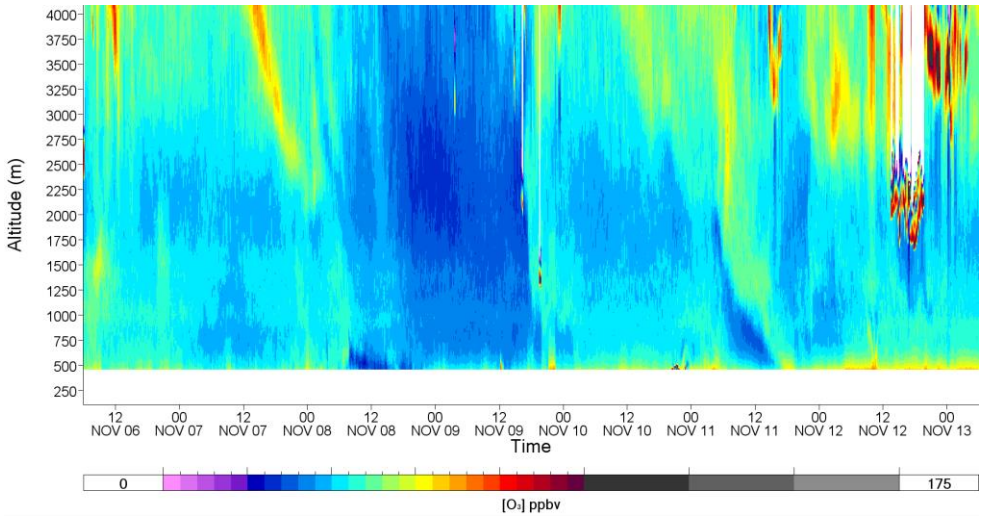
Impact of Stratospheric Intrusion (Nov 6-12, 2016)

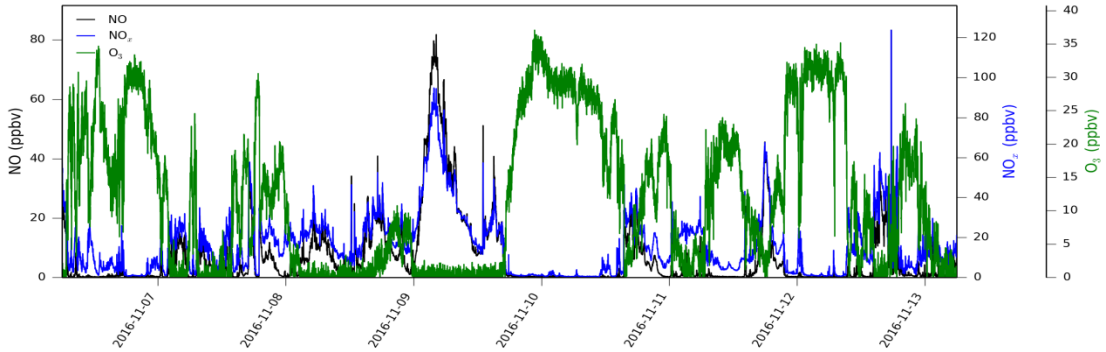




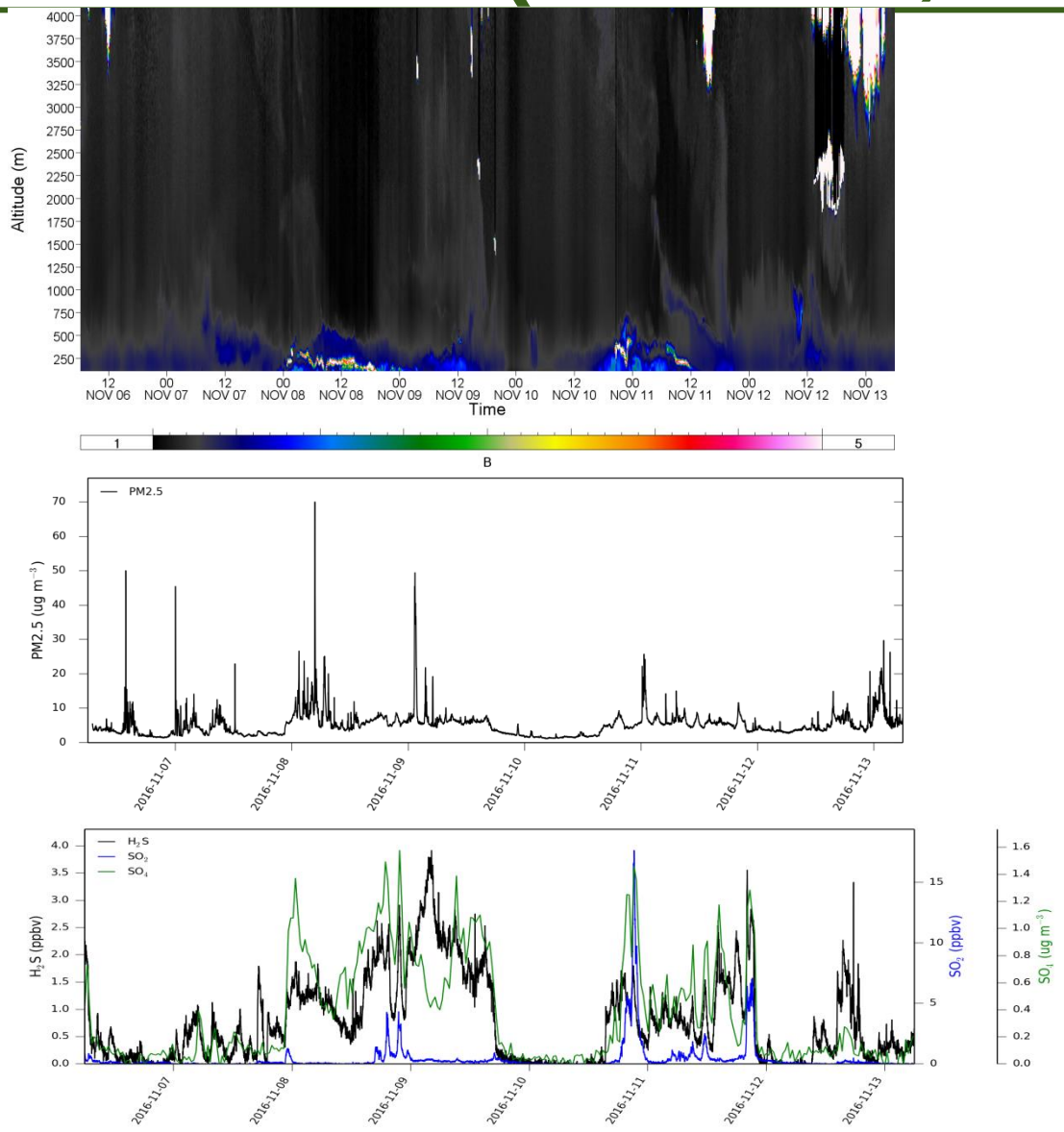
Canada

Ozone Lidar vs. NOx and Ozone at Ground Level (Nov 6-12, 2016)



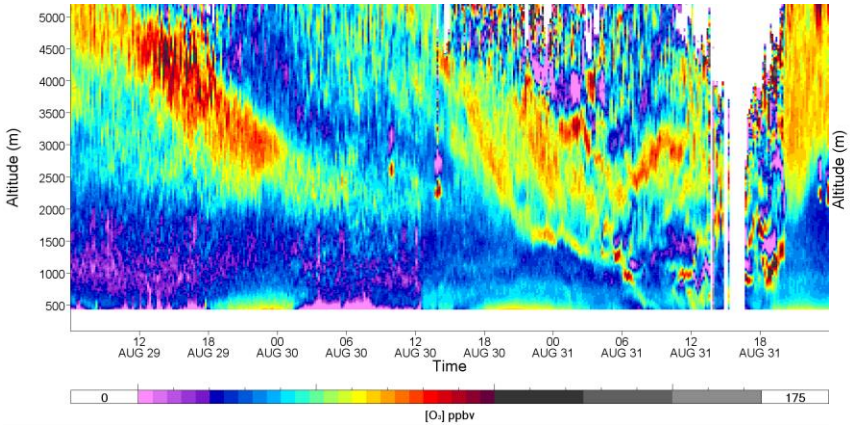


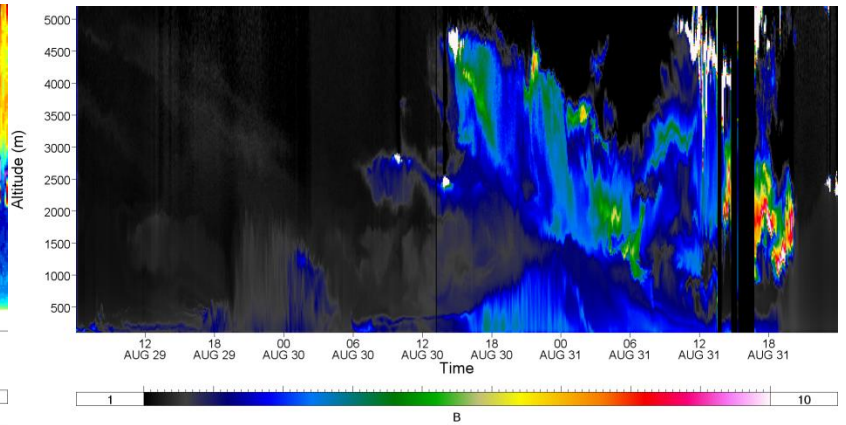
Aerosol Lidar vs. PM2.5 and sulfates Ground Level (Nov 6-12, 2016)

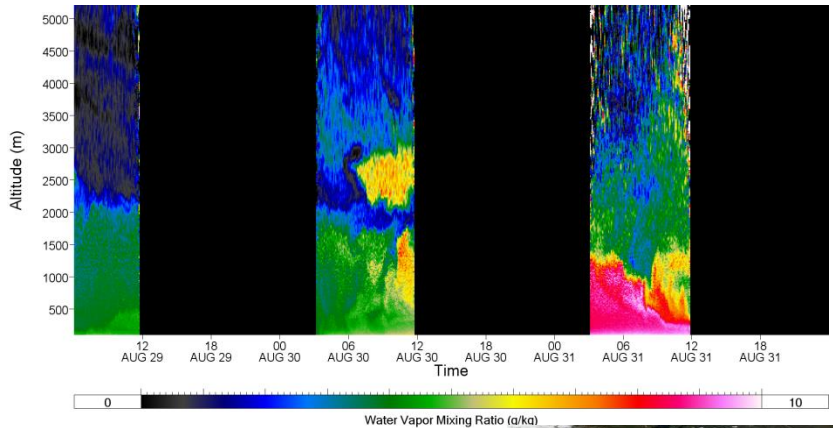


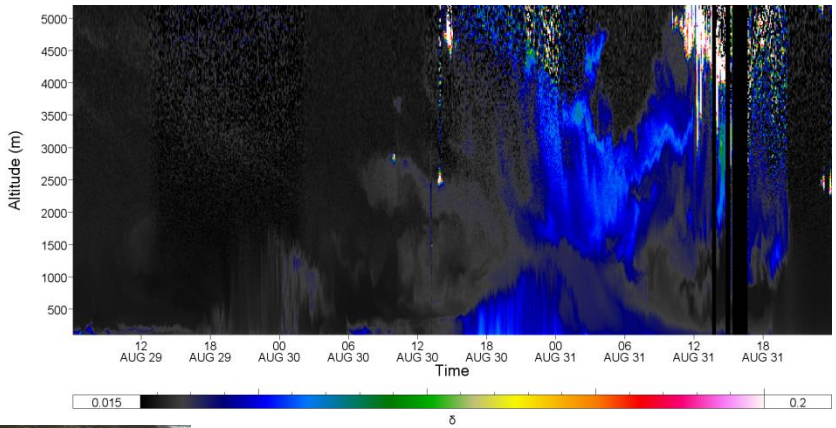
Canada

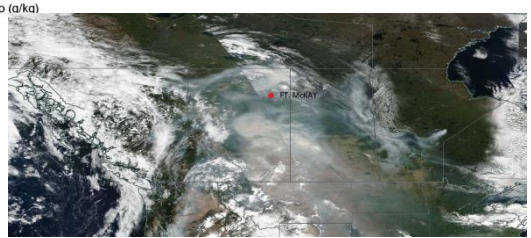
Forest fire plume impacting the region (August 29-31, 2017)











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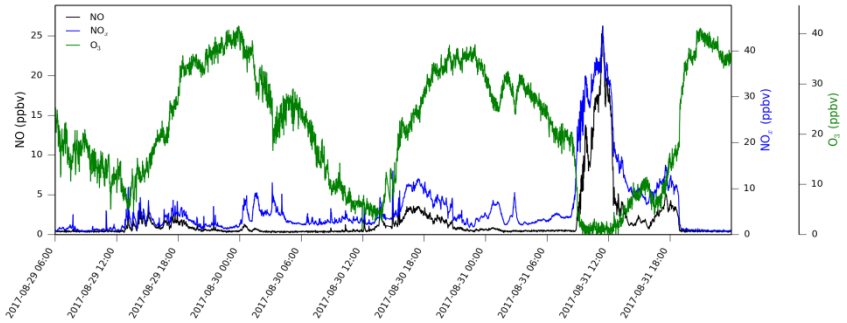
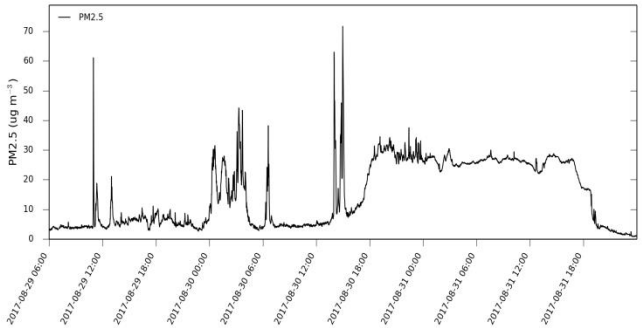
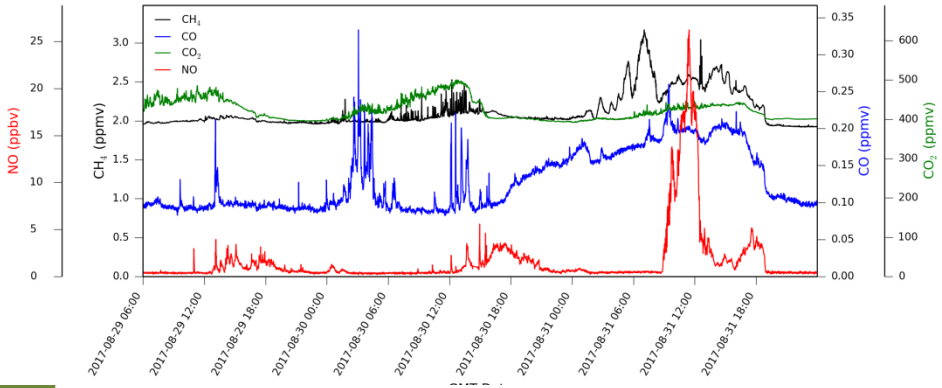
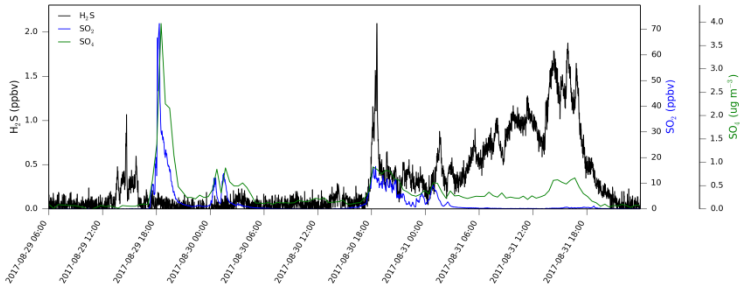
Forest fire plume impacting the region (August 29-31) – ground obs.

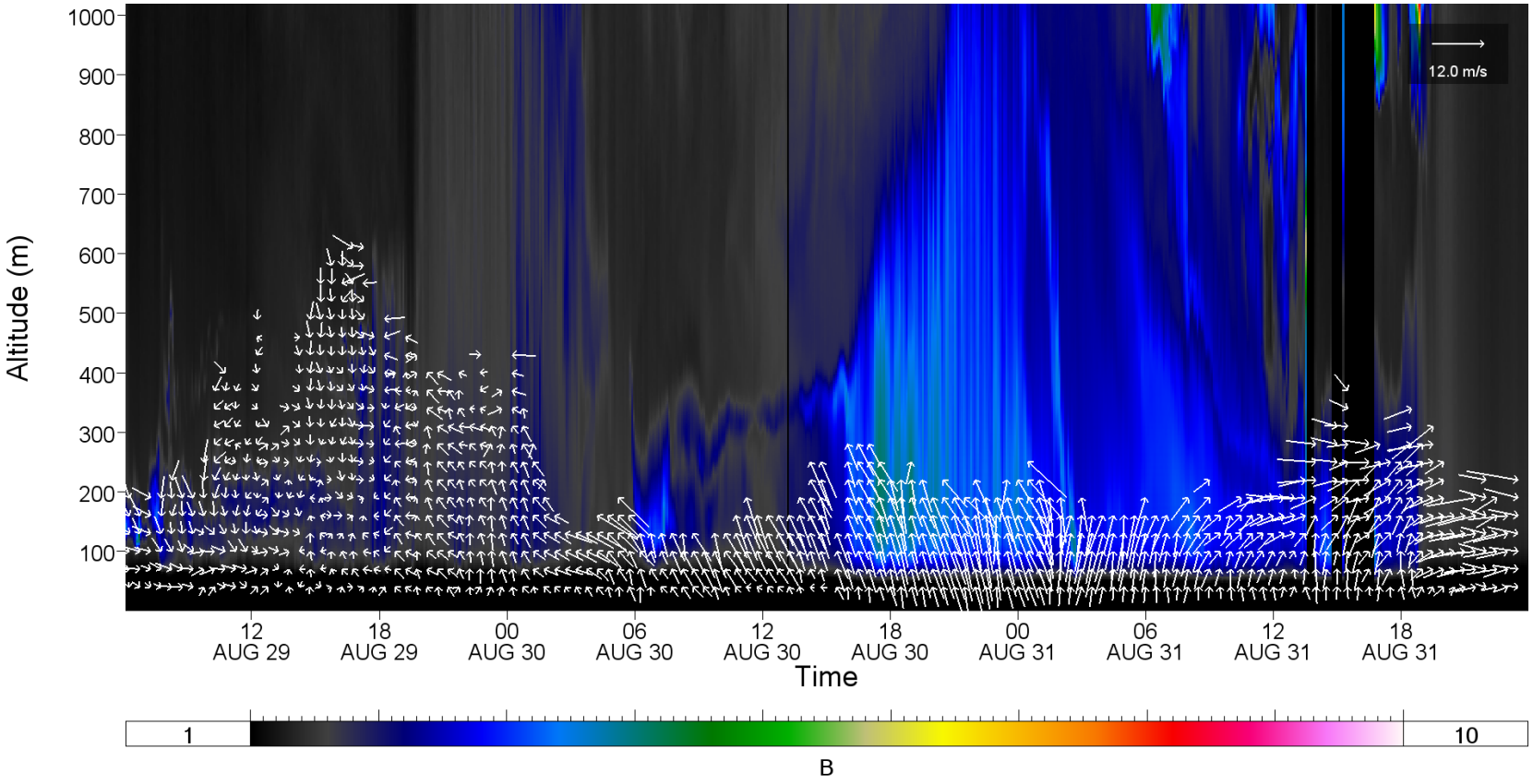




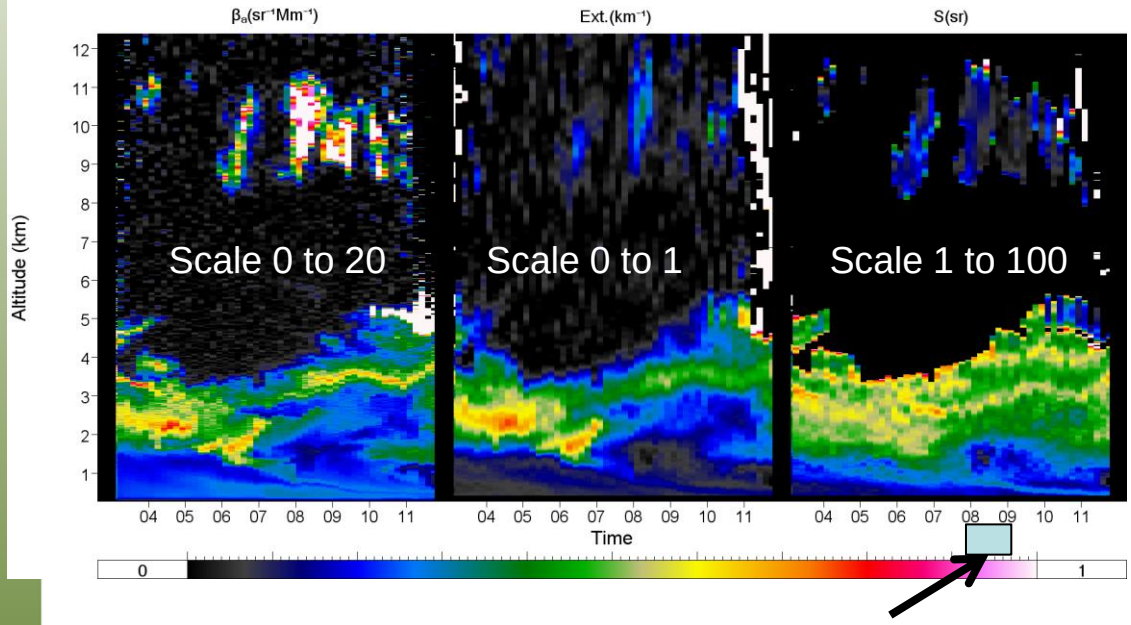




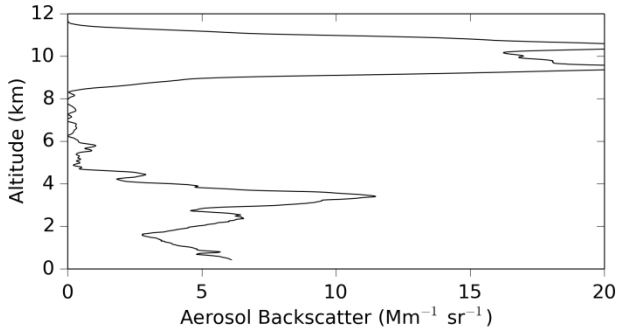
Aerosol Lidar with WINDRASS data superimposed

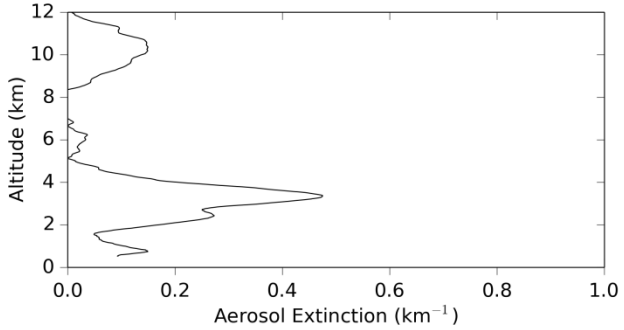


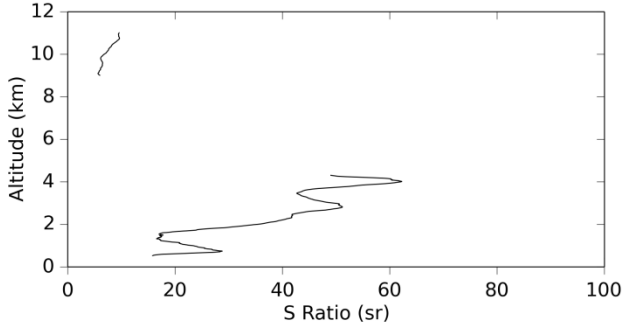
Forest fire plume – S ratio @ 355nm



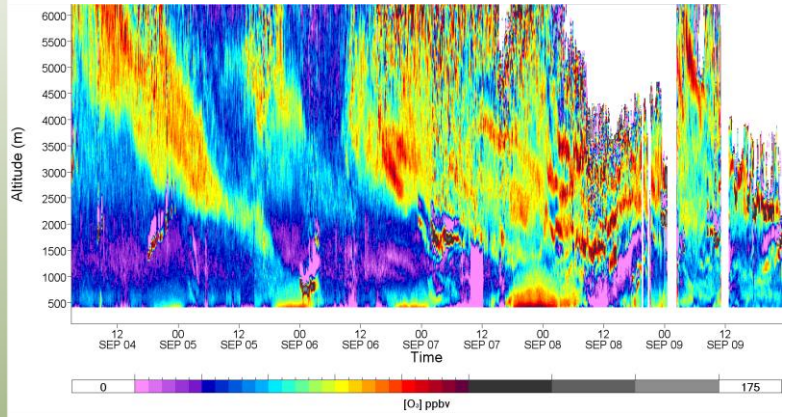
1 hour avg

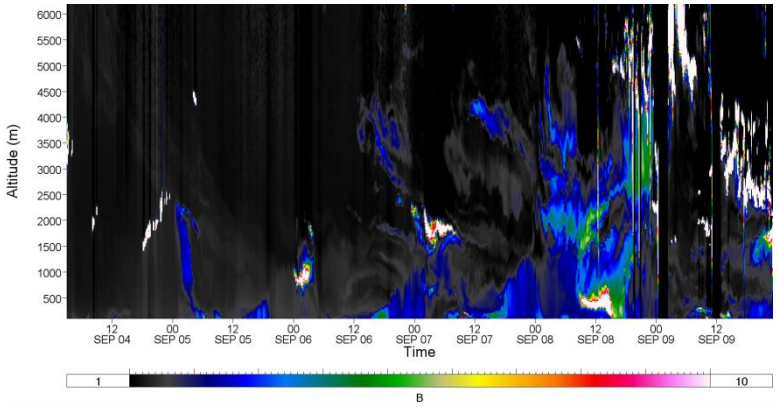


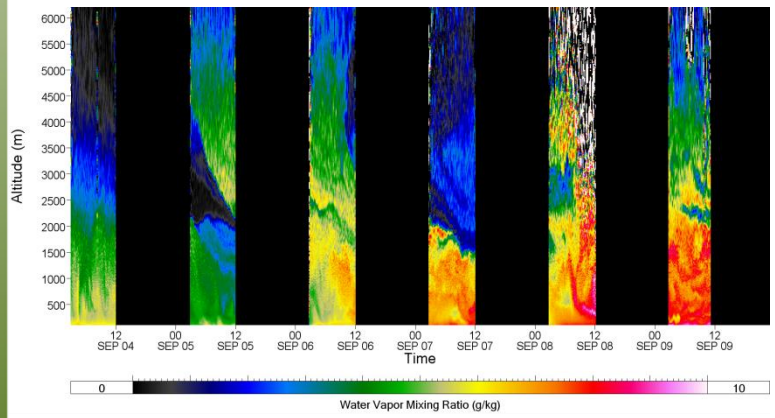


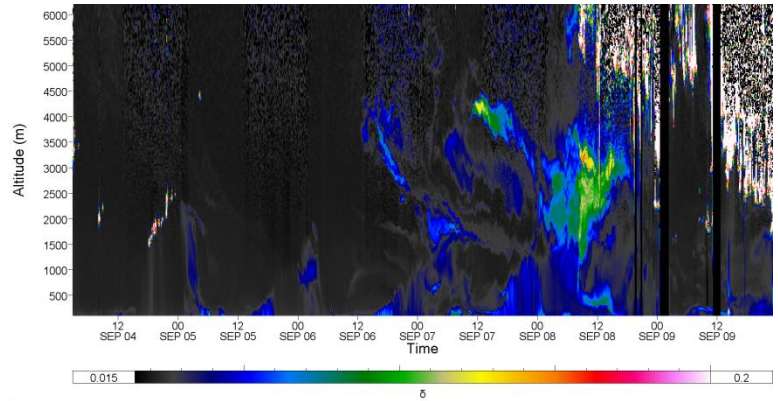


Stratospheric intrusion and Forest fire plume (Sept 4-9, 2017)

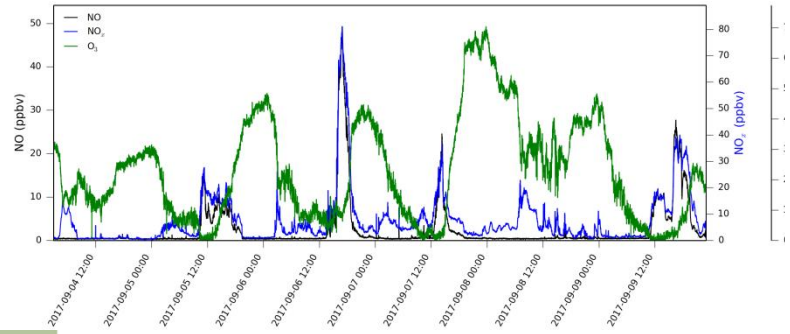


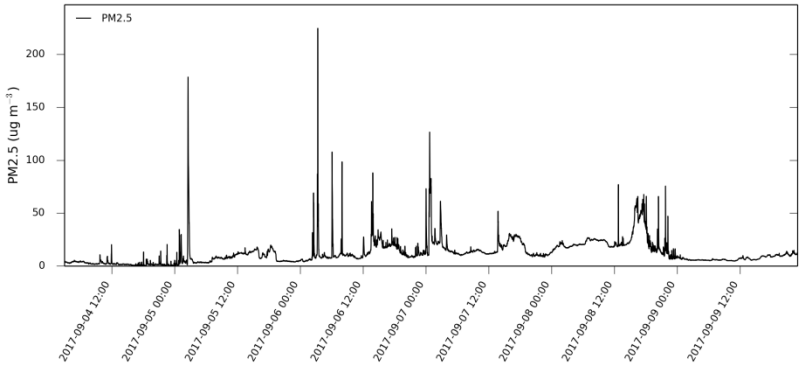


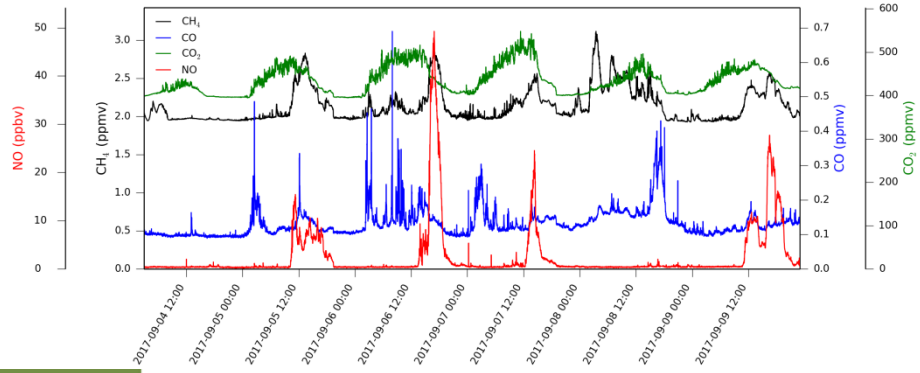


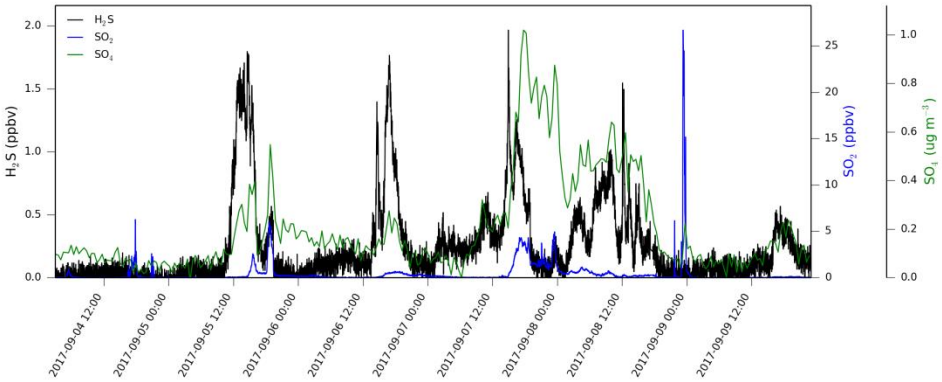


Stratospheric intrusion and Forest fire plume (Sept 4-9) – ground obs.









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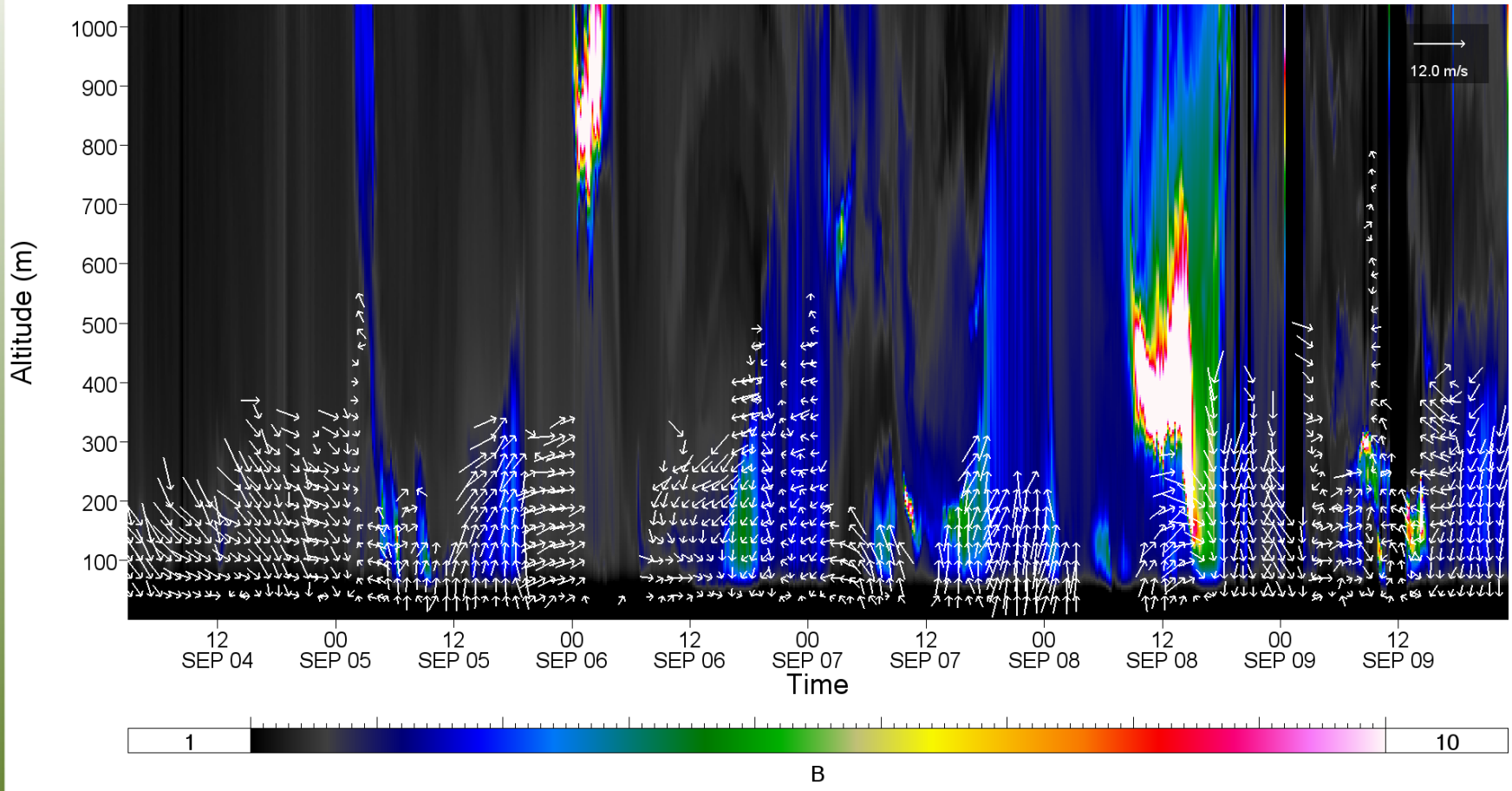
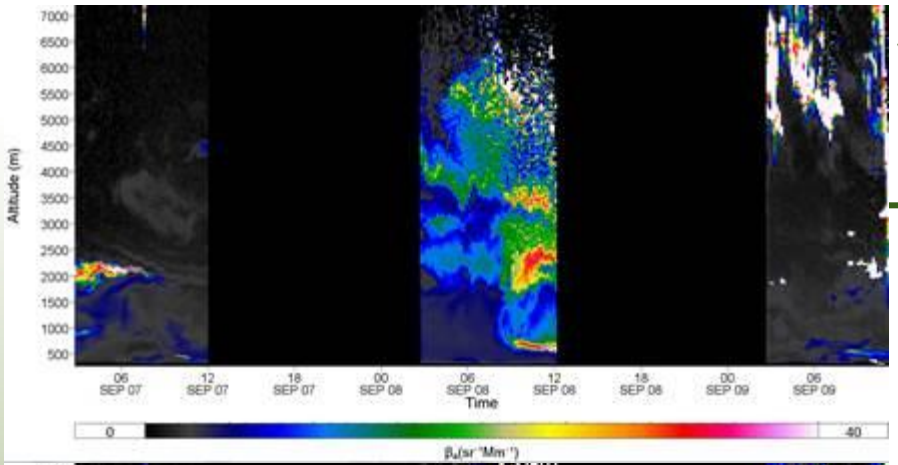
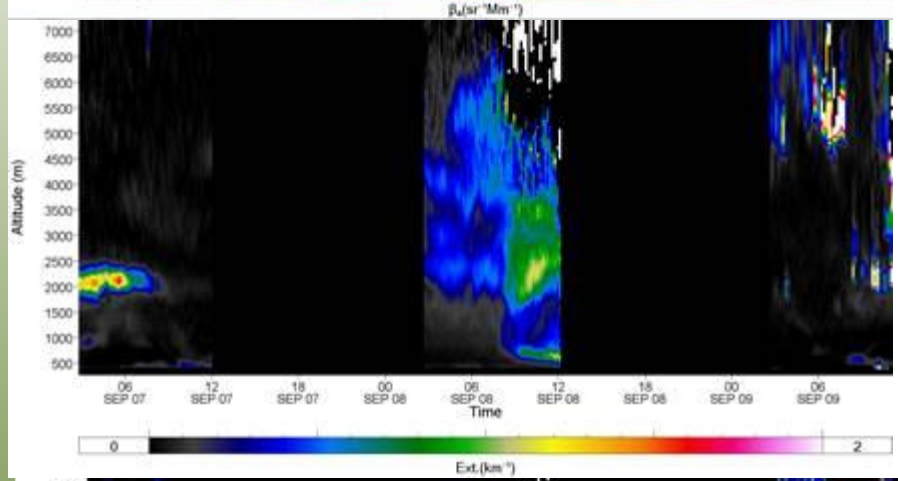
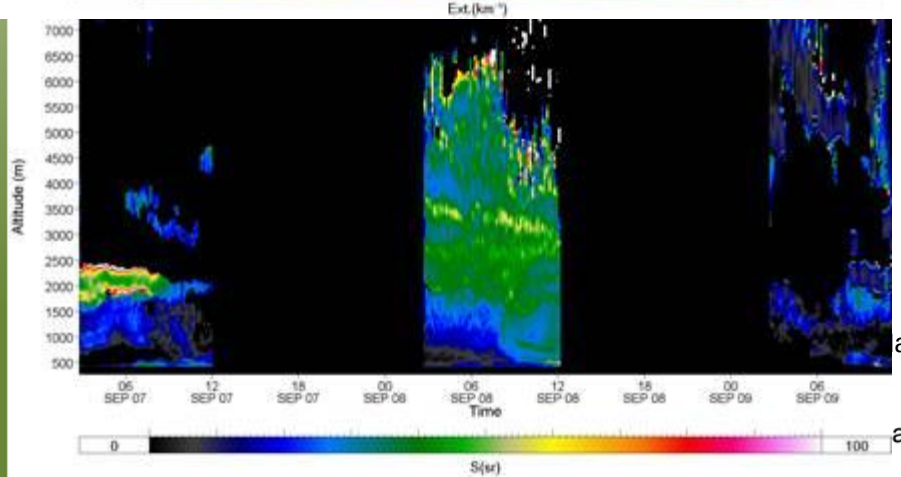


S ratio @ 355 nm







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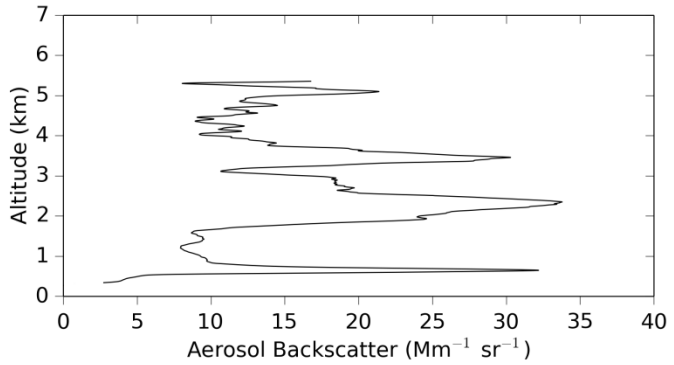
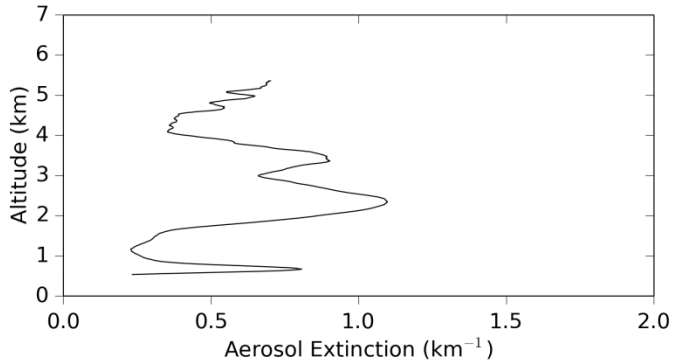
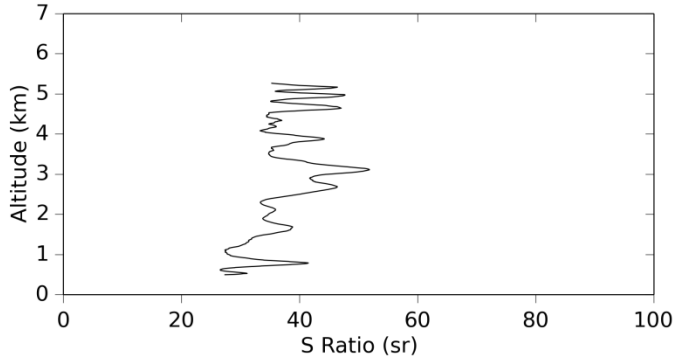
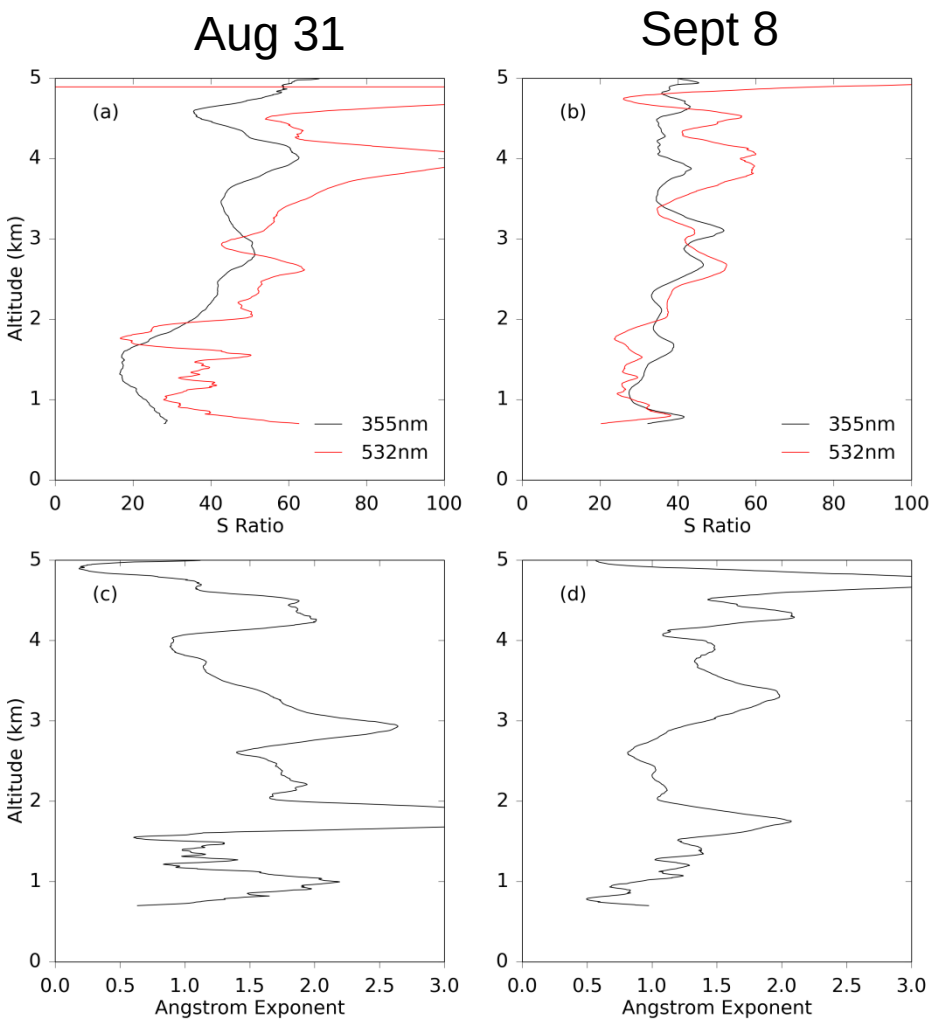


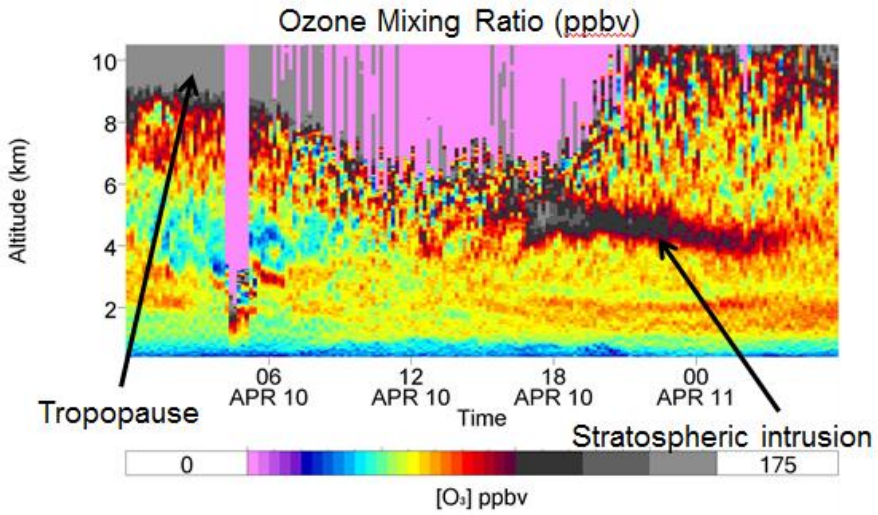


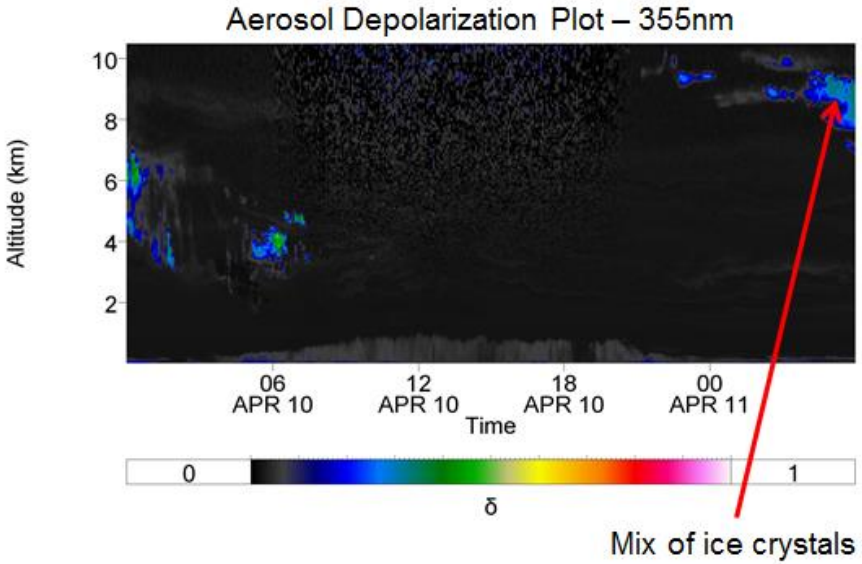


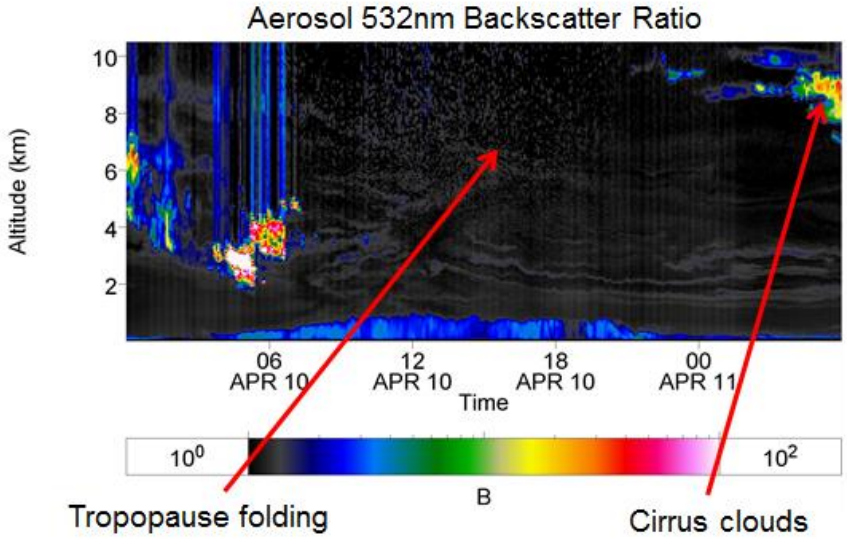
Forest fire plume – Angstrom Exponent two cases

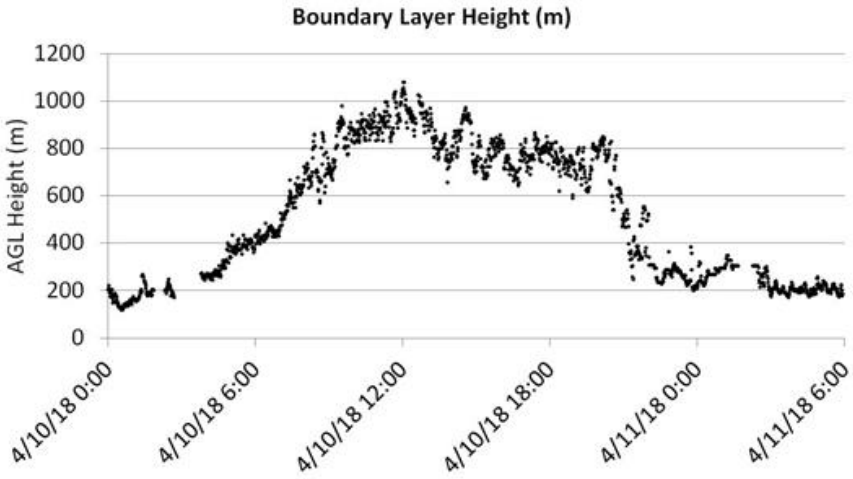


ECCC Aircraft/Model Validation over Oski Otin Ground Site.

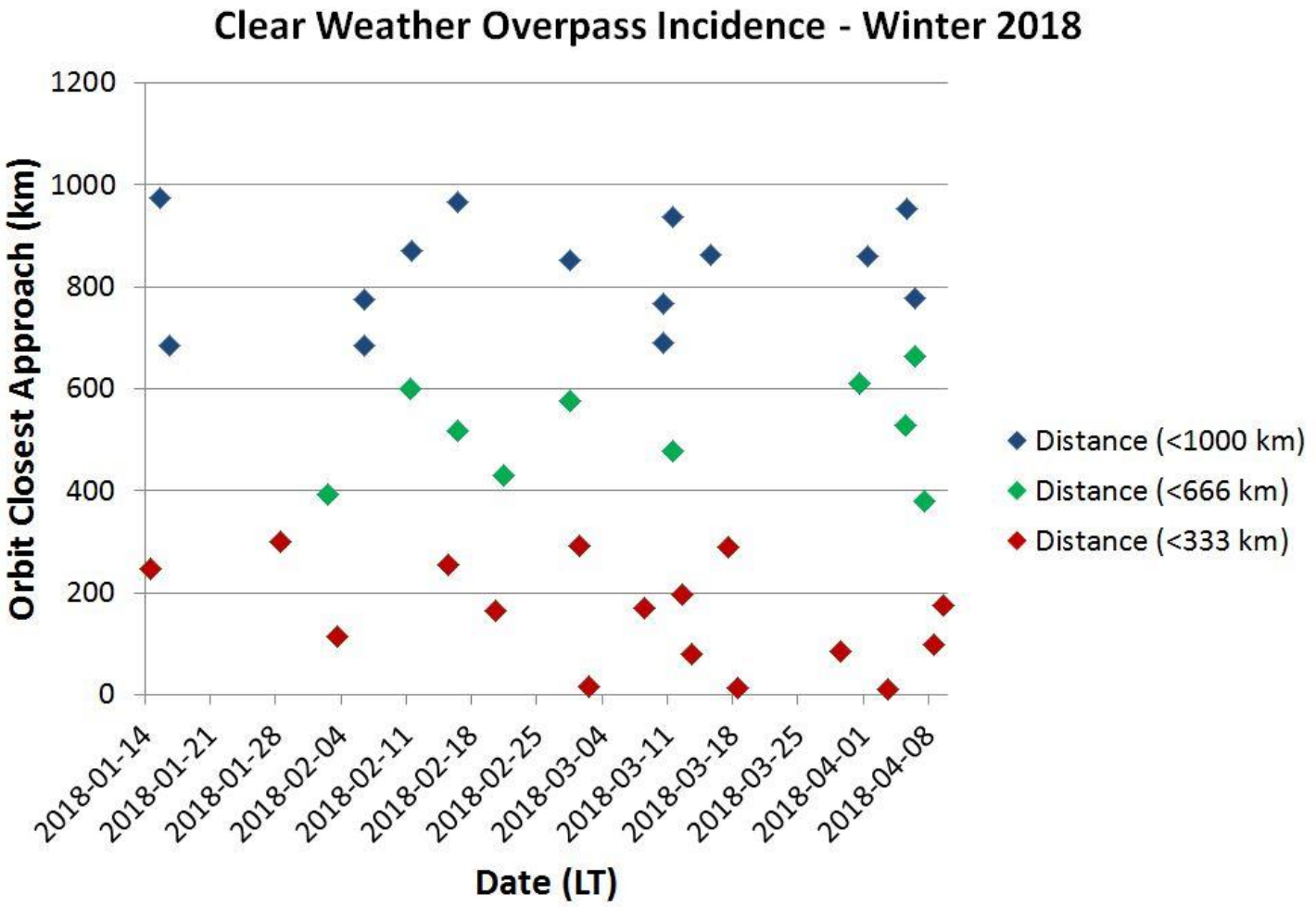




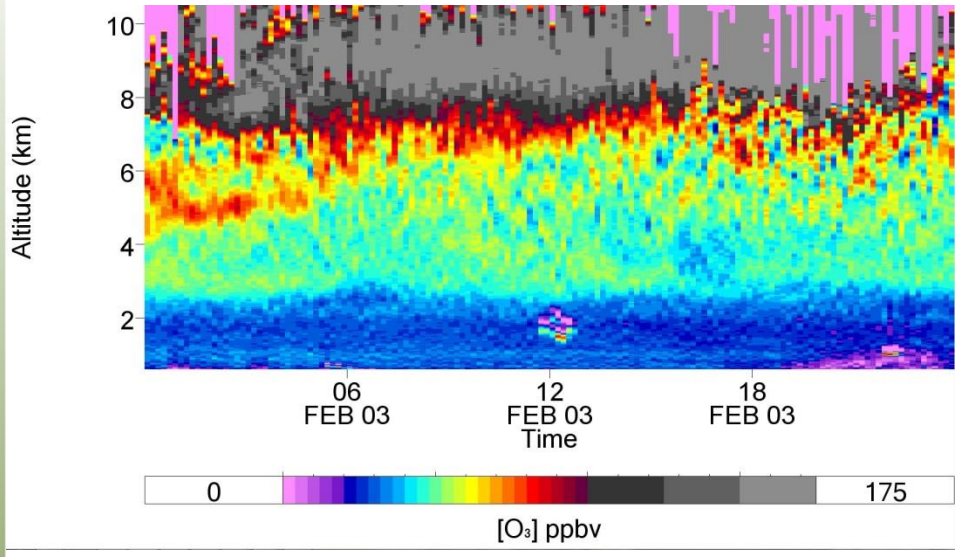


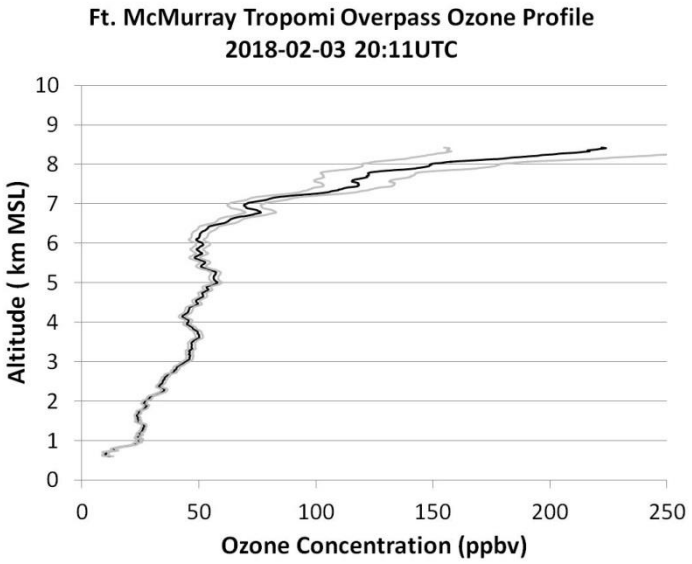


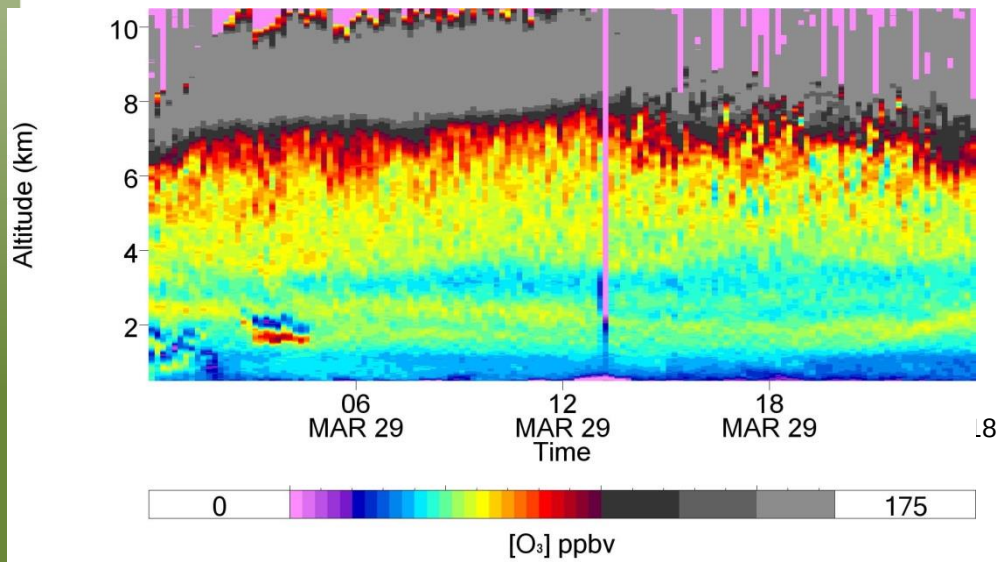
TROPOMI Validation - AMOLITE

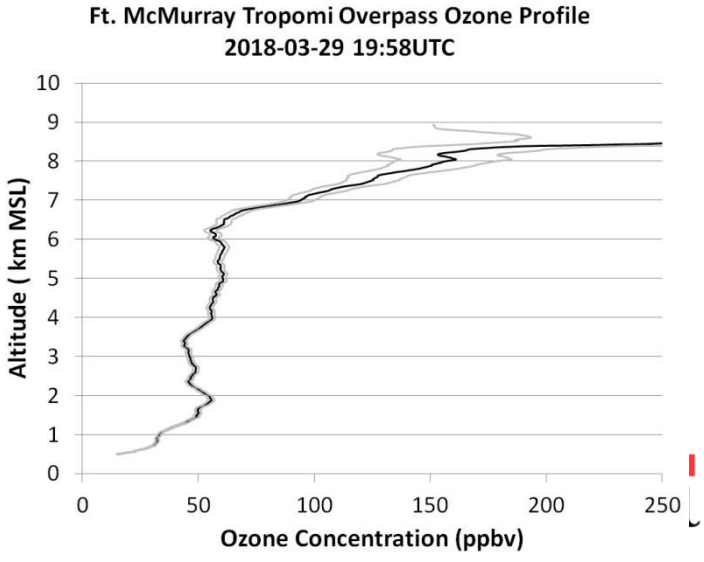


TROPOMI Validation - AMOLITE









Summary and Future Work

- the newly developed autonomous tropospheric ozone/3+2 aerosol lidar will add a unique capability for Environment and Climate Change Canada to explore the presence, vertical distribution and seasonal variability in the lower atmosphere
- the synergistic approach to simultaneous measure tropospheric ozone, aerosol and water vapour (night time) will provide an improved understanding of boundary layer and free tropospheric processes which impact visibility and air quality
- AMOLITE gives the vertical context for ground based and other remote sensors
- We have added a small telescope to the ozone DIAL to get closer to the ground (approx. 200m)