Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Some Canadian TEMPO-related Activities

Chris McLinden
Air Quality Research Division, Environment & Climate Change Canada (ECCC)

4th TEMPO Science Team Meeting
Washington, D.C. • 01-02 June 2016

Research Activities – CDA

- Currently ECCC has operational objective analyses of surface O_3, NO_2, SO_2, $PM_{2.5}$, PM_{10} over North America
  - Assimilation of these surface obs is being done in research mode
  - Forecasting surface based on assimilated column ozone
  - Near future: TropOMI products, MODIS AOD will be assimilated

- Longer term: development of an operational global/regional assimilation/forecasting system in place for 2019/2020 that will use:
  - EC GEM-MACH* operational AQ forecast model
  - North American surface stations (O_3, NO_2, $PM_{2.5}$)
  - TEMPO (+ TropOMI) measurements of O_3, NO_2, AOD
  - TEMPO SO_2, HCHO are TBD
  - Stratospheric profiles of NO_2 (pending availability)

* Global Environmental Multi-scale model - Modelling Air quality and CHemistry

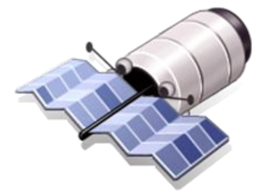
Air quality Chemical Data Assimilation plan

Operational

Objective Analysis Version 1 (OA-v1)

↓

Objective Analysis Version 2 (OA-v2)



EnVar Developments for Chemical Data Assimilation

Fall 2017

Regional Chemical Data Assimilation Version 1 (CDA-AQv1)

Spring 2017

Near-Real Time Ozone Assimilation and UV Forecasting (CDA-UV1)

Fall 2020

Global/Regional Air Quality Data Assimilation with EnVar (CDA-AQv2)

Fall 2020

Near-Real Time Ozone Assimilation and UV Forecasting with GDPS and interactive ozone (CDA-UV2)

Research Activities – Limb-Nadir matching

Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-138, 2016
Manuscript under review for journal Atmos. Meas. Tech.
Published: 4 May 2016

Atmospheric Measurement Techniques Discussions
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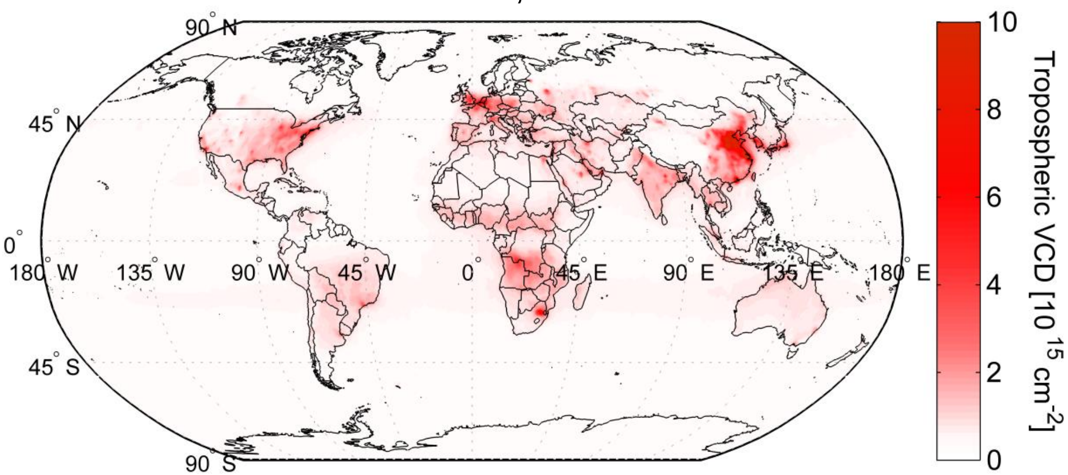
Limb–nadir matching using non-coincident NO_2 observations: Proof of concept and the OMI-minus-OSIRIS prototype product

C. Adams et al., 2016

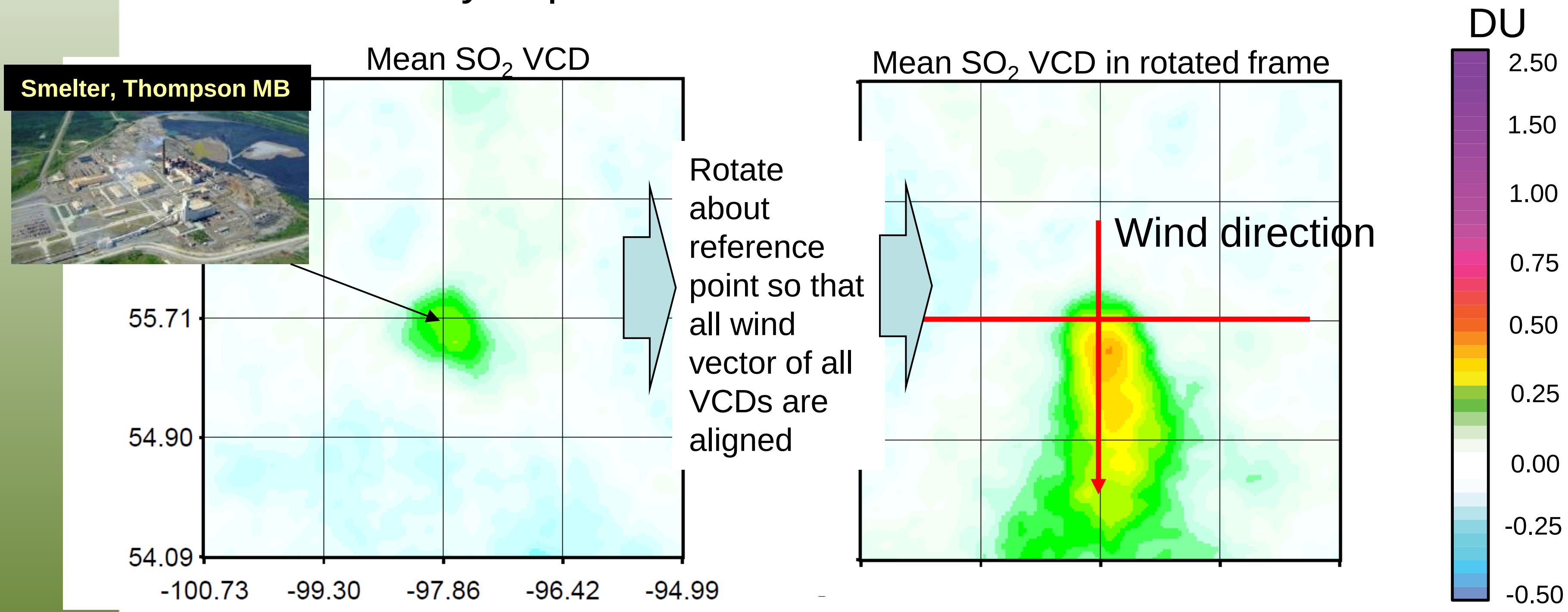
OMI-minus-OSIRIS, 2008 mean



- Used OSIRIS stratospheric NO_2 profile, adjusted to OMI LST, to remove stratosphere from OMI
- Showed good promise, despite issues with SCD high-bias
- Ultimately we'd hope to use limb NO_2 is an assimilation system to help isolate tropospheric column

Research Activities – Emissions

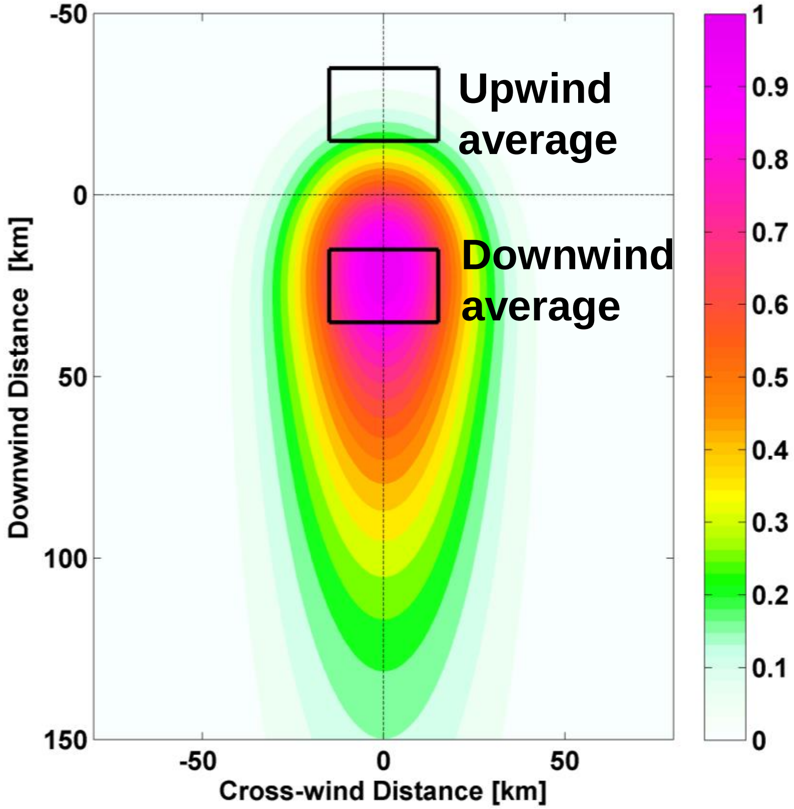
- Application of OMI to emissions of NO_2 and SO_2
- Merge OMI and wind information → fluxes
- Downwind decay of pollutant can be used to derive emissions



Research Activities – Emissions

- Can also be used to locate sources
- Compare downwind average with upwind; if larger, then source is present

- Consider every point on a high-resolution grid and perform this test:
  - Align wind vectors by rotating about this point
  - Determine downwind-upwind difference in SO_2 VCD



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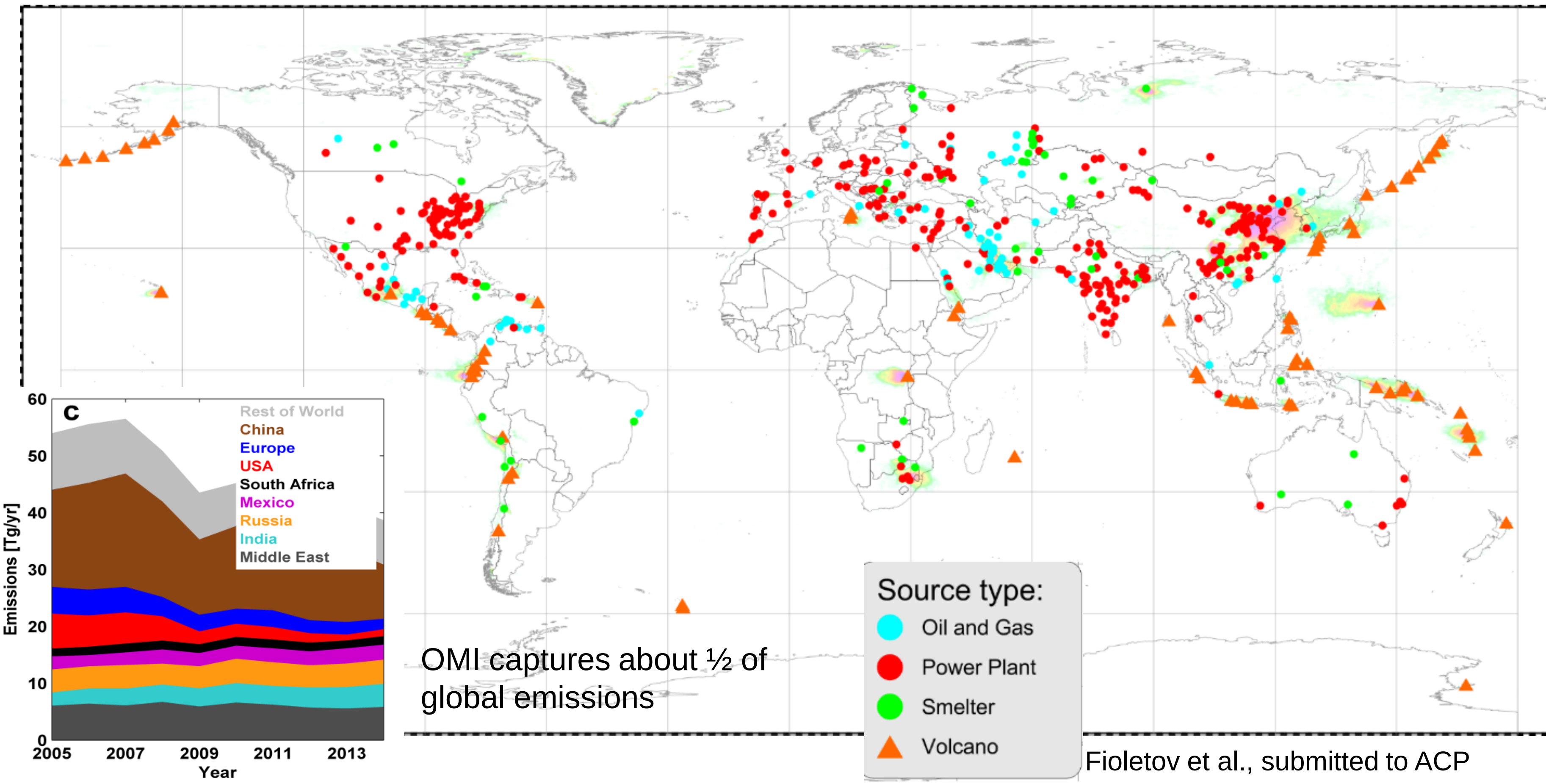
OMI SO_2 “catalogue”

- Sources identified using OMI PCA SO_2, wind reanalysis, and a detection algorithm
- Check sources against databases of power plants, smelters, oil and gas refineries, other industrial sources, and volcanoes
- At present, ~500 sources identified and annual emissions calculated (298 Power Plants, 53 Smelters, 64 Oil and Gas industry-relates sources, 78 Volcanos) [annual emissions vary between 30 to 5000 kt/yr].
- ***The catalogue includes site locations, source types and annual emission estimates for 2005-2015***



Fioletov et al., submitted to ACP

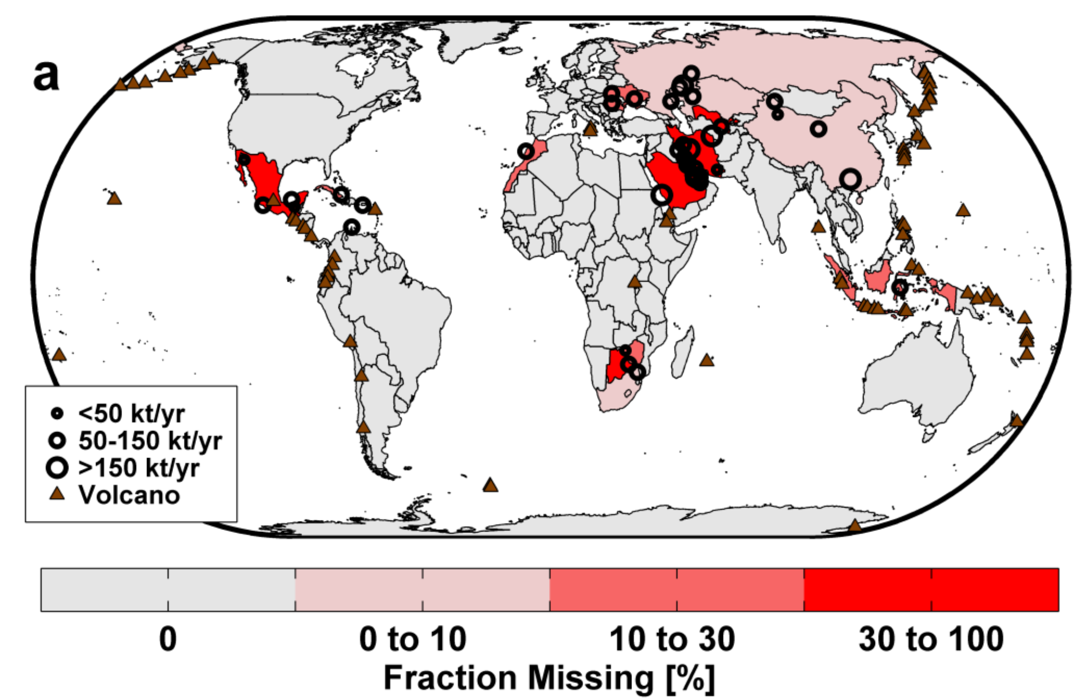
nature geoscience

LETTERS

PUBLISHED ONLINE: 30 MAY 2016 | DOI: 10.1038/NGEO2724

Space-based detection of missing sulfur dioxide sources of global air pollution

Chris McLinden[1]*, Vitali Fioletov[1], Mark W. Shephard[1], Nick Krotkov[2], Can Li[2,3], Randall V. Martin[4,5], Michael D. Moran[1] and Joanna Joiner[2]



- Find ~40 sources are missing from leading emissions inventories (HTAP, MACCity, …)
- We estimate that ~12% of SO_2 emissions are unaccounted for
- Densest cluster in Middle-East
- Emissions for 75 (now 78) volcanos are estimated

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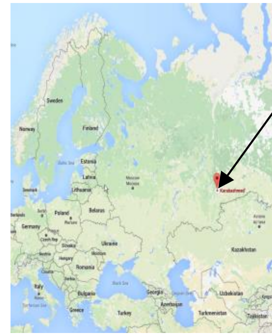
Examples: large discrepancies between reported and estimated emissions

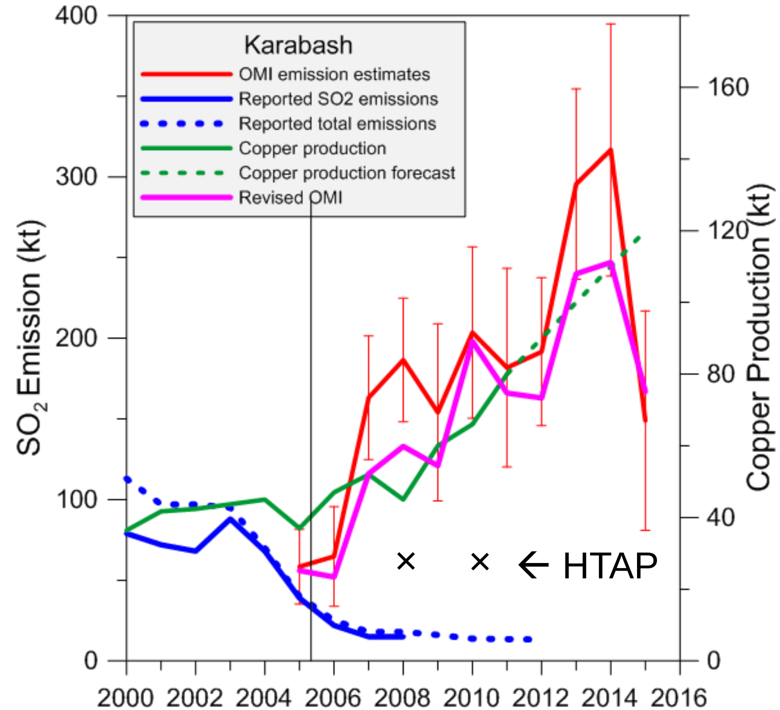
- Karabash and its outskirts have been subject to acid rain since the 1970s; the copper-smelting process produces sulfuric gases, and no purification of emissions was undertaken
- A critical worsening of the ecological situation forced the Karabash copper plant to stop work from 1989 to 1998
- The plant resumed operation in 1998 with no modernization of the treatment facilities
- In 2005, the plant owner reported installation of scrubbers, but complains about high pollutions continued
- In July 2010, the Prosecutor General's Office of the Russian Federation legally obliged Karabash smelter to modernize its production and reduce harmful emissions



Karabash smelter (founded in 1837) is one of the oldest and largest copper smelters in Russia. An SO_2 signature is clear in OMI

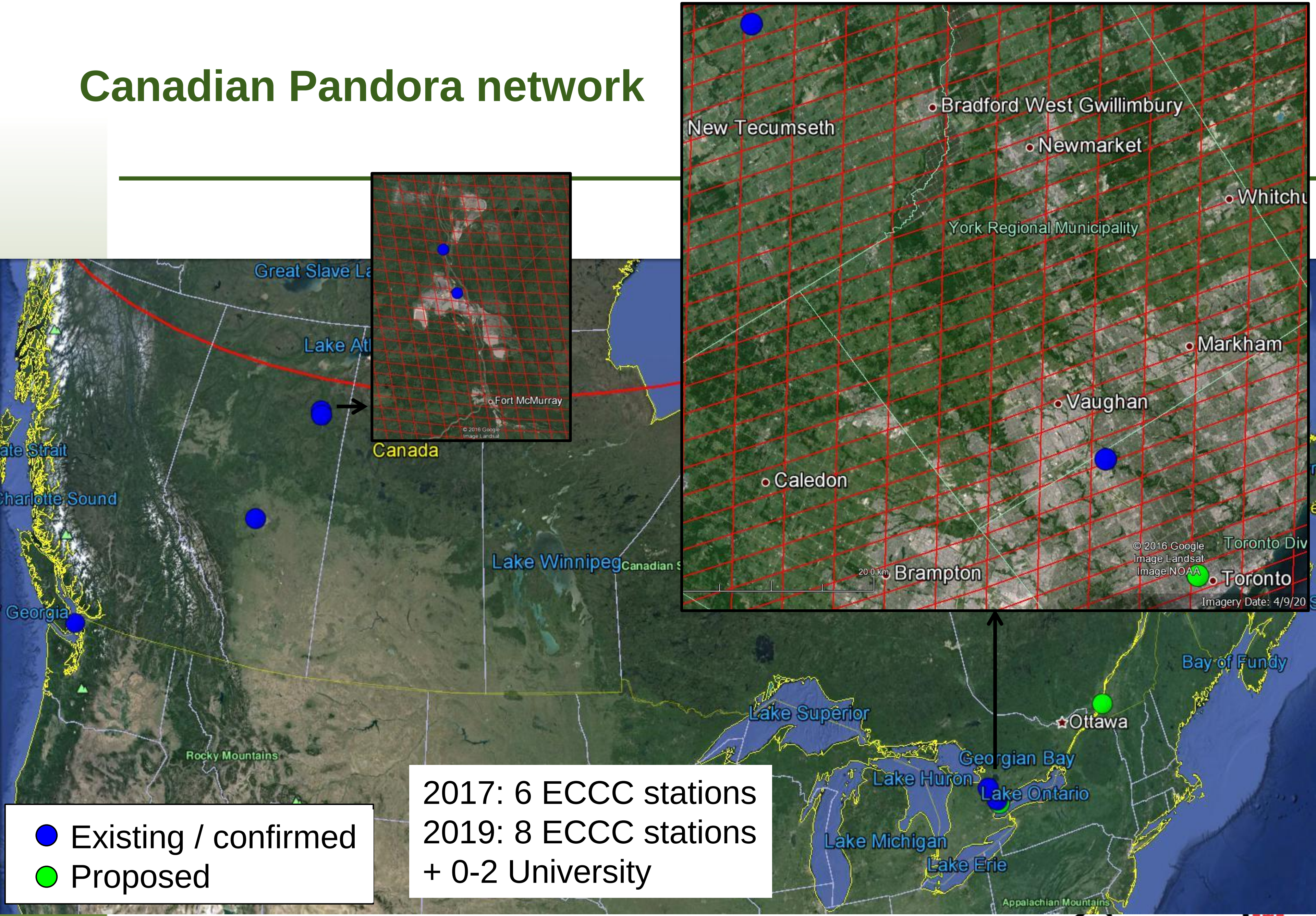
Ignoring nearby sources

Simultaneous fit to all regional sources



- OMI detection limit ~30 kt/yr for annual SO_2 emissions
- What would we expect from TEMPO?
  - With an order of magnitude better spatial resolution and sampling
  - Lower detection limit?, better separation of nearby sources?
  - We want to explore using output from ECCC GEM-MACH air quality forecast model (at 2.5 km resolution)
  - Also examine: NO_x (via NO_2), PM (via AOD)

Canadian Pandora network



- Existing / confirmed
- Proposed

2017: 6 ECCC stations
2019: 8 ECCC stations
+ 0-2 University

Pandora SO_2

Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-54, 2016
Manuscript under review for journal Atmos. Meas. Tech.
Published: 1 April 2016

Atmospheric Measurement Techniques
Discussions
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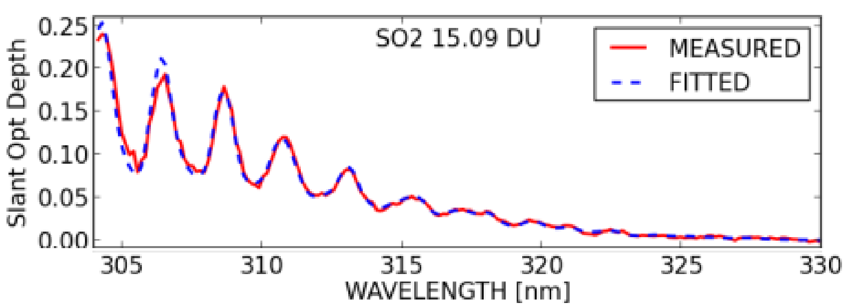
Sulphur dioxide (SO_2) vertical column density measurements by Pandora spectrometer over the Canadian oil sands

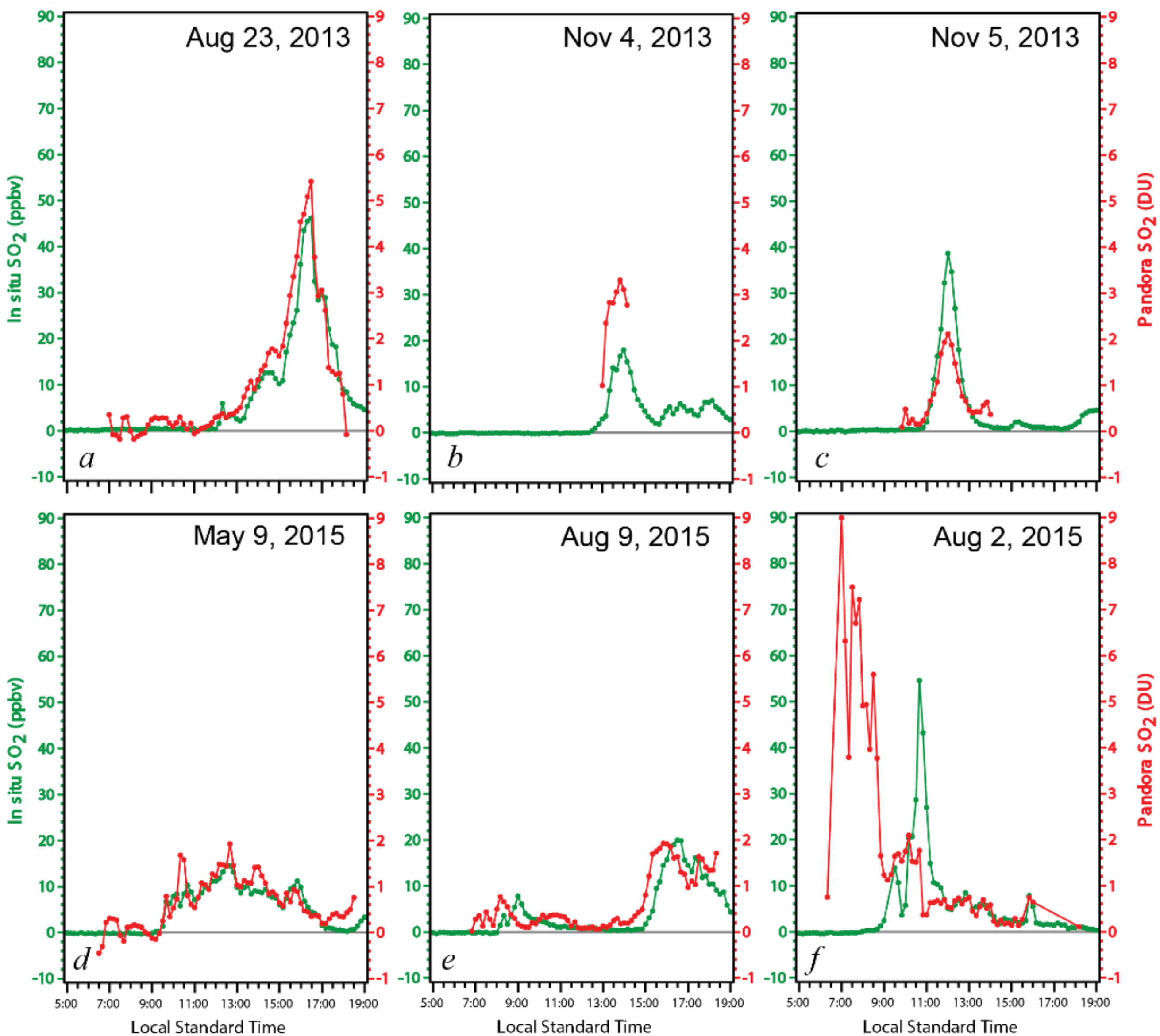
V. Fioletov et al., 2016

- Statistical error of fit <0.05 DU
- Precision, derived using parallel measurements from two co-located Pandoras, is 0.17 DU



Installation on roof of oil sands trailer

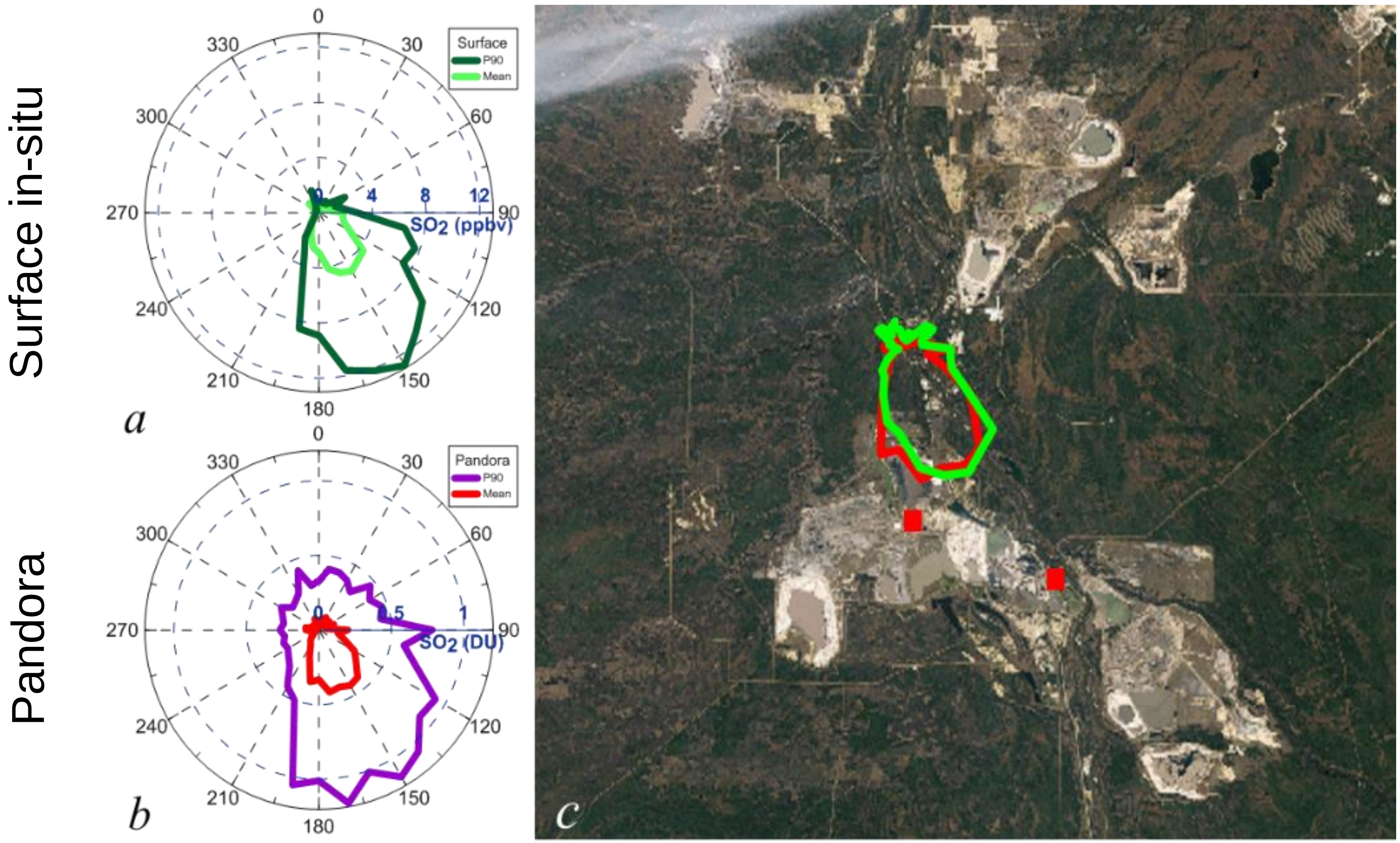
SO_2 VCD and surface concentration



Vertical Column Density (in DU, 1 DU = $2.69 \cdot 10^{16}$ molecules$\cdot$cm^{-2}) measured by Pandora spectrometer at Fort McKay and in situ SO_2 concentration (ppbv)

Note that the vertical scales are the same on all 6 plots.

Surface SO_2 and VCD vs. surface winds



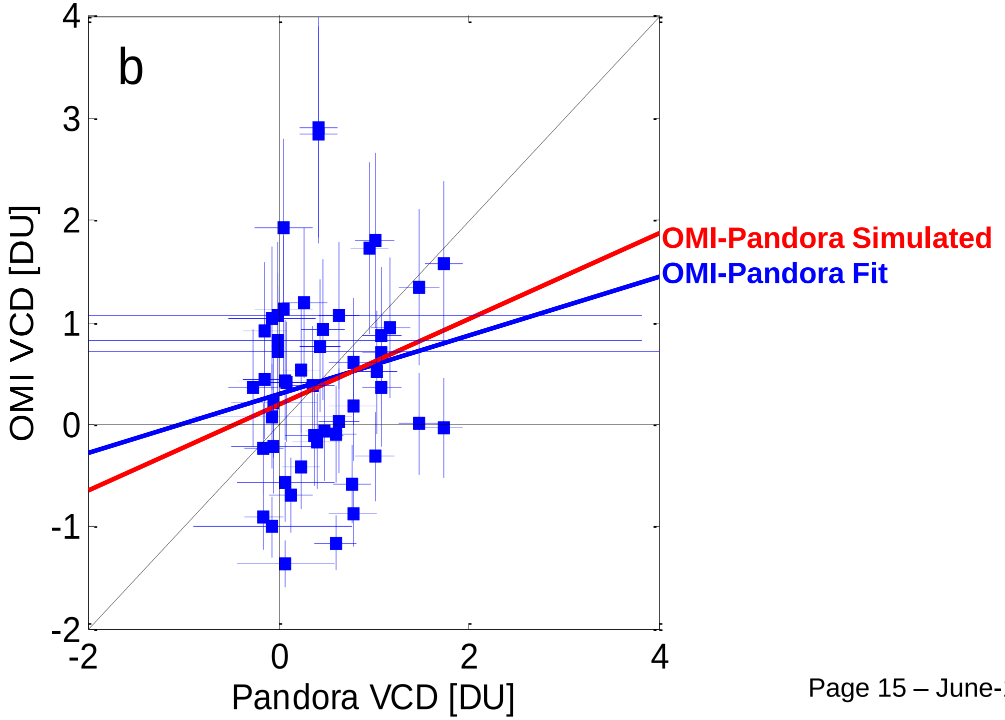
The mean and 90th percentile of in situ SO_2 concentration (a) and Pandora SO_2 VCD (b) at Fort McKay as a function of the surface wind direction.

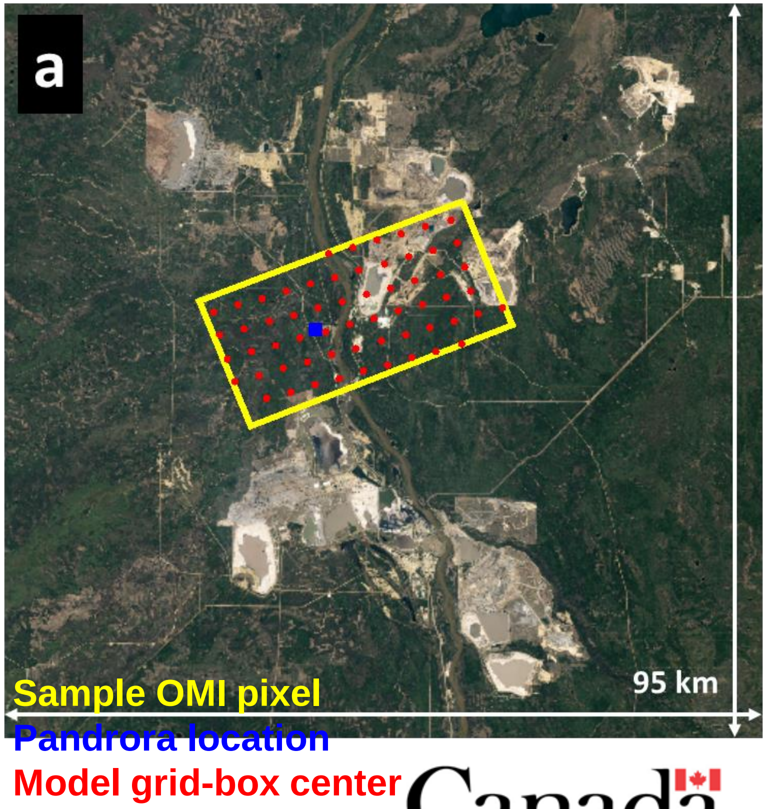
Both Pandora and in-situ data shows similar patterns: high SO_2 values are associated with south-east winds (c). The two red squares indicate the major SO_2 emission sources.

Pandora-OMI comparisons

What should we expect from a comparison given their difference in spatial resolution?

Use actual OMI pixels to sample a high-resolution AQ model (2.5 km)





ECCC Validation Activities

- deploying Pandora spectrometers to select monitoring sites
  - First four sites: Toronto, Oil sands, CARE (N of Toronto), Edmonton
  - 6+ should be in place for TropOMI validation
  - 8+ expected for TEMPO validation
- Other networks: Brewer, Aerocan/Aeronet, ozonesonde, surface monitoring
- participating in TropOMI validation
- Aircraft campaigns:
  - Aircraft measurement (oil sands / fracking) campaign being planned March/April/May 2018
    - Allow for comparisons over snow / snow-free / partial-snow pixels
  - Support at ECCC for TEMPO validation campaign