2D Sensitivity Analysis of TEMPO NO2 at Canadian Latitudes

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Introduction

Questions:

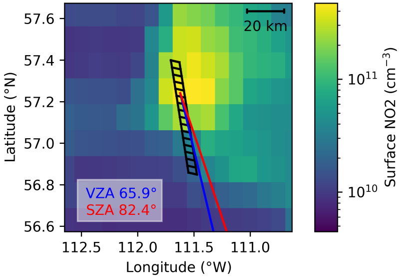
- Where exactly does a measured trace gas signal come from?
- How is it distributed horizontally?
- Under what conditions could this negatively impact traditional retrievals?
- Could this be used to extract more information from measurements?

Motivation:

- alternative retrieval algorithm tailored to Canadian challenges
  - snow, high zenith angles (solar and LOS), limited sunlight
- high zenith angles means horizontally distributed light path
- horizontal gradients become more important with high spatial resolution
  - albedo gradients: snow, coastlines
  - pollution gradients: emissions, urban centers

Setup

- winter scene at Canadian oil sands
  - high zenith angles
  - potential for snow (but realistic albedo data was not used)
  - high NO2 concentration and horizontal gradients at surface
- took small column of TEMPO pixels
- 2D atmospheric state put on altitude-angle grid in the vertical plane over these pixels
- gridpoints perturbed to calculate AMF via finite-difference



Surface NO2 concentration, selected TEMPO pixels, line of sight, and incoming solar direction.

Method

Traditional 1D DOAS method:

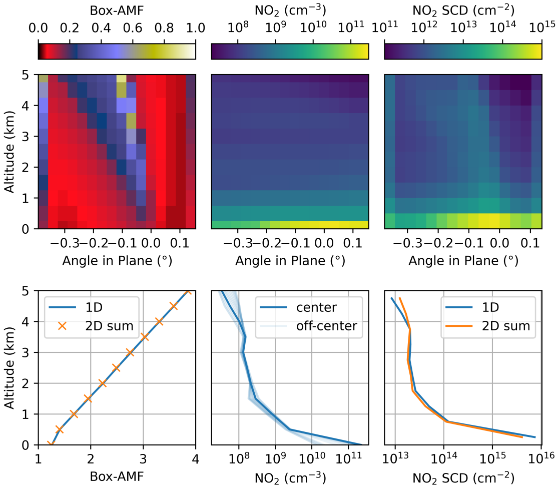
$$AMF = \frac{SCD}{VCD} = \frac{\sum_i a_i v_i}{\sum_i v_i}$$

1. box-AMFs a_i from radiative transfer
2. NO2 profile v_i is assumed
3. total AMF is the weighted average of the box-AMFs in each layer
4. total AMF transforms measured SCD into VCD

Equivalent 2D method:

$$AMF = \frac{SCD}{VCD} = \frac{\sum_i \sum_j a_{ij} v_{ij}}{\sum_i v_{i0}}$$

1. box-AMFs a_{ij} from radiative transfer
2. NO2 field v_{ij} is assumed
3. total AMF is the weighted average of the box-AMFs in each cell
4. total AMF transforms measured SCD into VCD



Worst-case albedo:

- 2D AMF: 0.7469
- 1D AMF: 1.3286
- AMF diff: 77.9 %
- VCD diff: -43.8 %

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Albedo	Mixed	High	Low	Zero
VCD ($\times 10^{16}\mathrm{cm}^{-2}$)	0.58	0.58	0.58	0.58
1-D SCD ($\times 10^{16}\mathrm{cm}^{-2}$)	0.77	1.87	0.21	0.11
2-D SCD ($\times 10^{16}\mathrm{cm}^{-2}$)	0.43	1.53	0.18	0.09
1-D AMF	1.33	3.21	0.37	0.18
2-D AMF	0.75	2.63	0.31	0.16
AMF % Difference	77.9	22.1	18.1	18.3
VCD % Difference	-43.8	-18.2	-15.3	-15.5

Results for mixed (worst-case, 0.0 at center, 1.0 elsewhere), high (1.0), low (0.05) and zero (0.0) albedo.

Results:

- neglecting horizontal effects in the chosen scenario results in VCD error on the order of:
  - uniform albedo: 15 %
  - worst-case albedo: 40 %

Opportunities:

- localized analysis (e.g. emission estimates)
- reduce a priori dependence by analyzing multiple pixels simultaneously?
- estimate horizontal averaging kernel?

Implementation Challenges:

- computation time / table parameterization
- accurate high resolution a priori data
- realistic data (clouds topography)