Deep Neural Network Framework for Inverting Remotely Sensed CO_2 Measurements

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Introduction

- Extreme weather events with increasing intensities are recurring at alarming rate.
- 18% of the world GDP is exposed to climate change risk.
- Measuring and controlling the emissions causing climate change, such as CO_2, is crucial for effective risk mitigation.

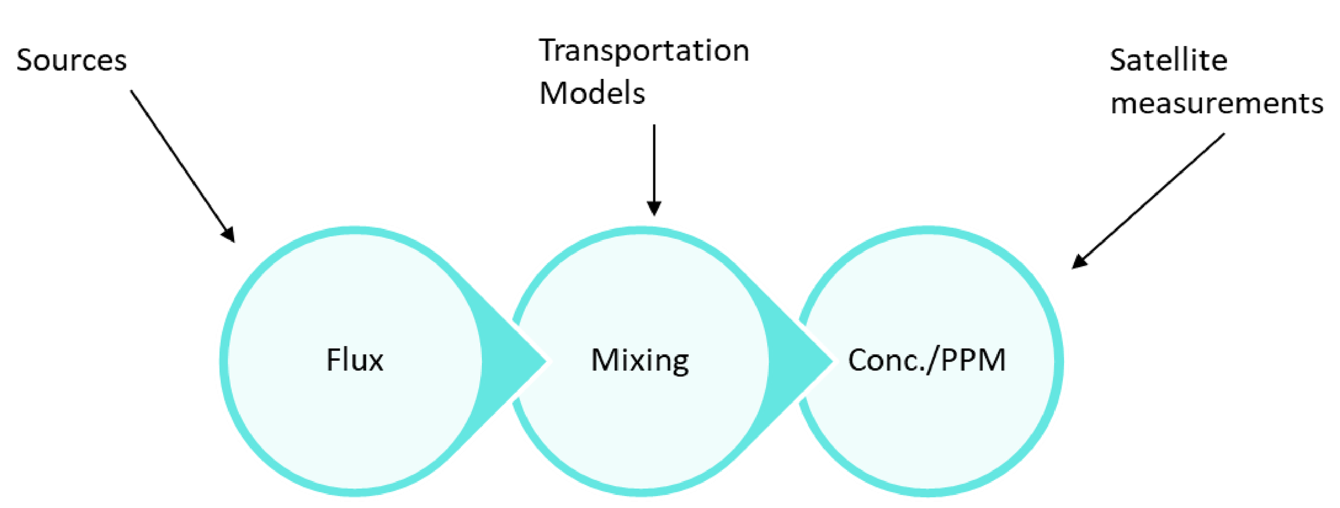
Flux estimation

Two main methods for estimating fluxes (mass per unit time) are:

- The first, bottom-up methods involve gathering detailed inventory and activity data, and the associated emission factors.
- The second, top-down methods involve measuring concentrations (often in ppm) of the pollutant in the atmosphere and inferring the sources with the help of numerical transport models. Two major frameworks commonly used are Ensemble Kalman filter and the 4-D Variational method.
- Collecting and maintaining detailed inventory, emission factors and so on is a complex and costly undertaking. Top-down methods are computationally complex and require domain knowledge.

Idea

- Modern deep learning can learn non linearities and once trained well can be used without any inputs from experts.
- Can we use modern deep learning techniques to invert concentration?

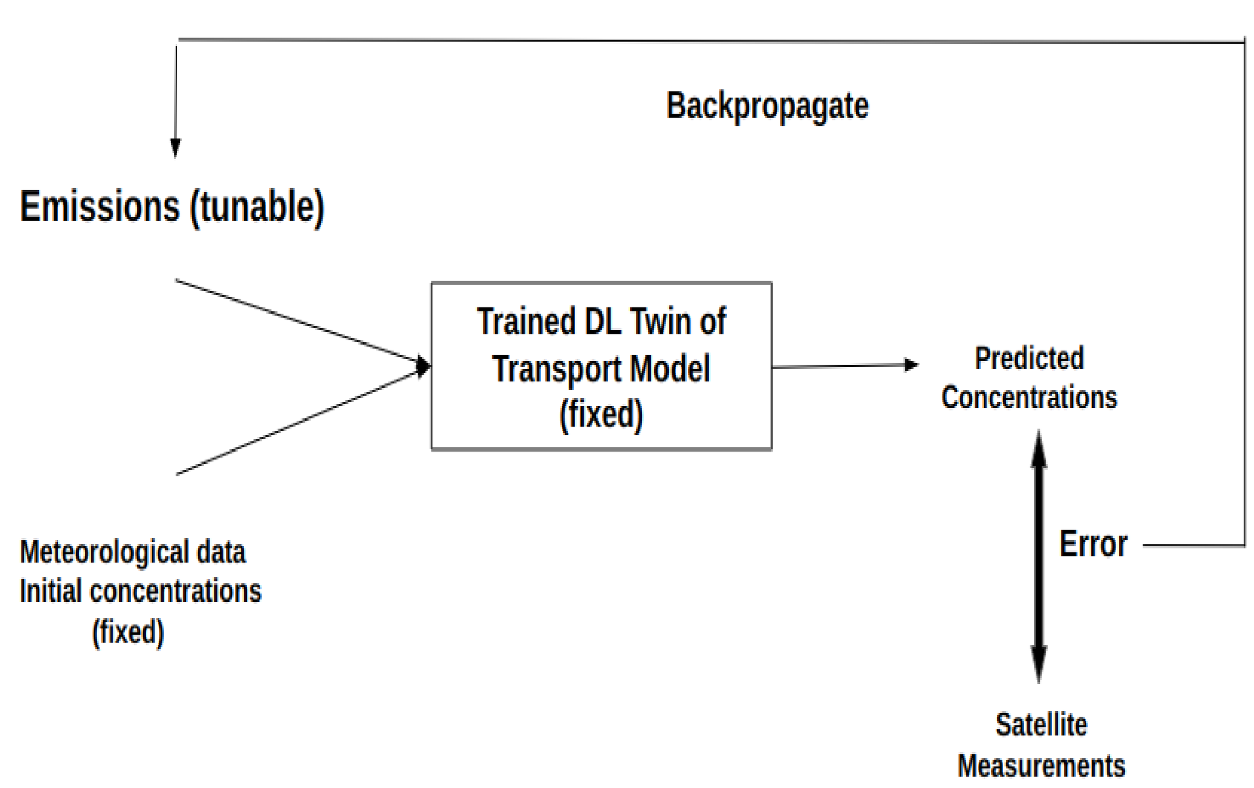


We propose unified network doing double duty

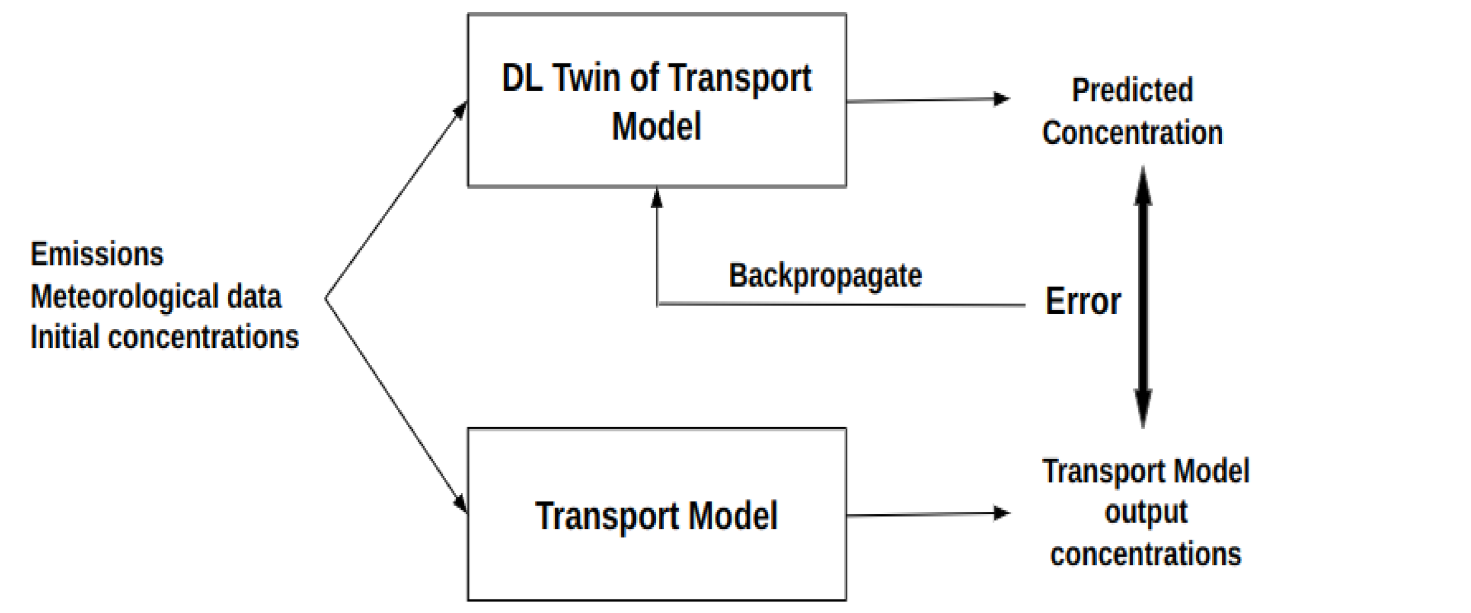
- DL for twin for transportation, and
- DL for flux correction based on the consistency of the measurements and model output.

Method

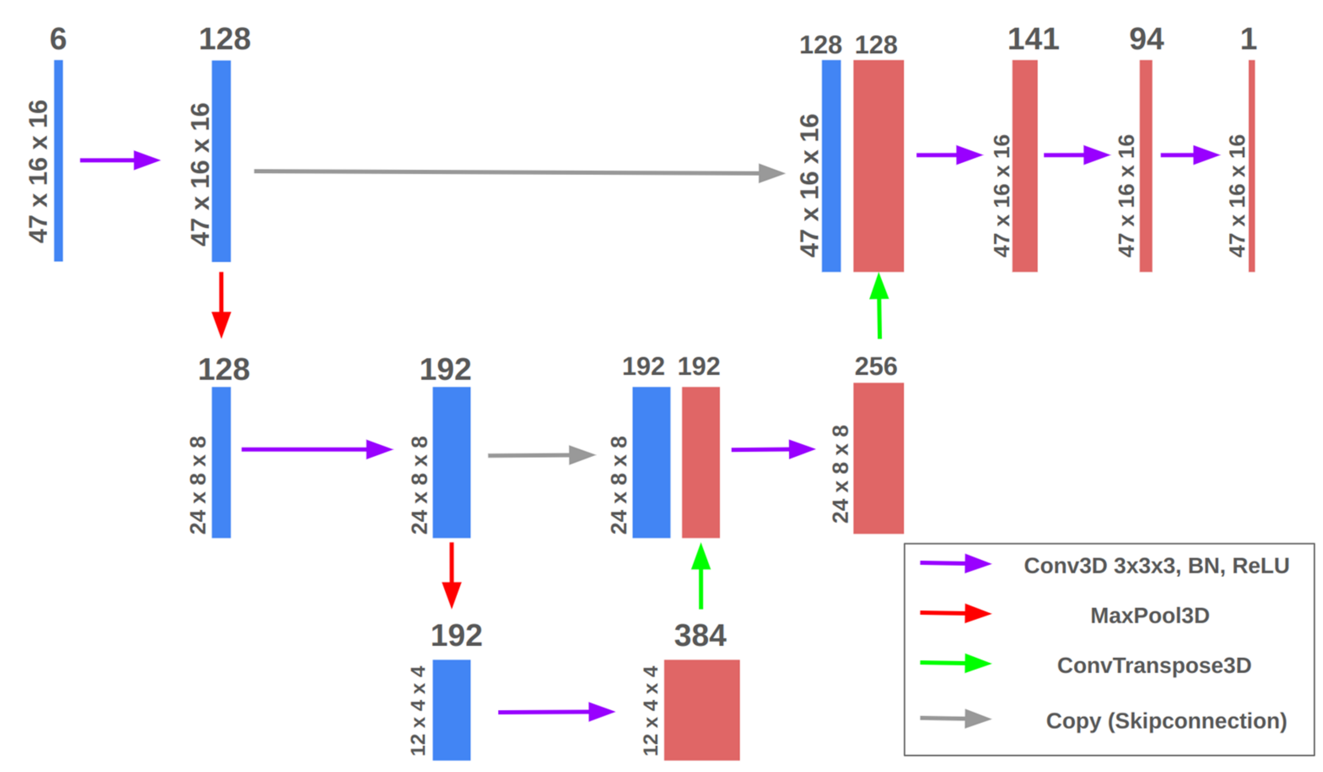
- Our proposed deep learning model performs a double duty – it predicts the concentration by taking flux inputs – matching transportation model, the same model is used to correct the fluxes in iterative manner - such that fluxes are consistent with the transportation and the satellite measurements.
- The illustration shows the part 1 that is building a digital twin of transportation, the part 2 that is inverting the concentration to correct the fluxes.



Part 1: Take numerical transport model > train its deep learning twin



Part 2: DL twin model + satellite concentration measurements corrected emissions

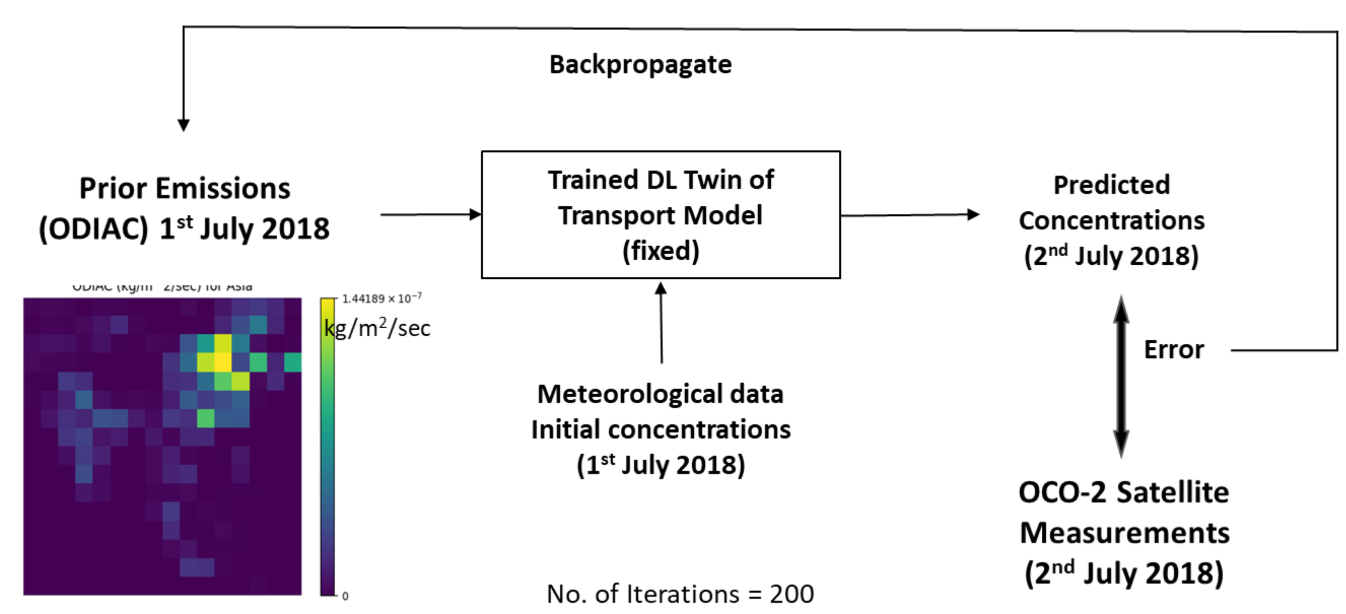


DL model architecture

Training data for digital transportation twin

- Emissions (fossil fuels …) + initial concentrations + meteorological data (NASA) were given as an input to numerical GEOSCHEM model for generating daily average concentrations.
- Processing Grid: 4° x 5° (Asia), Model Size: 7.6 Million parameters

Results and Validation



- Predict the daily averages using the input condition as per the ODIAC and aggregate for a year
- Total emissions for 2018 according to EDGAR report: (17.811 Gt) Gt
- Total emissions of the region (extrapolated to the whole year) increase from (prior) 19.6 Gt to 60.2 Gt

Concluding remarks

Preliminary results by the proposed method are encouraging. We are working on improving the model by:

- building more accurate model using better computing infrastructure,
- incorporating additional complex transportation processes and domain knowledge in the formulations.

Key takeaways

- A unique deep learning framework for estimating pollutant fluxes
- Potential to create most accurate flux data product

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