



# Super-Resolution of GOME-2 Nitrogen Dioxide (NO<sub>2</sub>) data using Sentinel-5P for training.

Deep Learning for Atmospheric Composition

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## GOME-2

- Launched in 2006, 2012, 2018 on board of MetOp A/B/C
- Resolution at the equator of  $40 \times 80 \text{ km}^2$

## TROPOMI

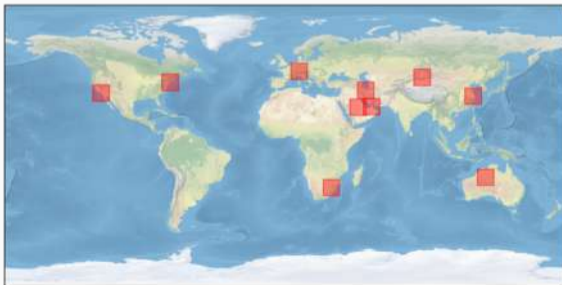
- Launched in 2017 on board of Sentinel-5P
- Resolution at the equator of  $3.5 \times 7 \text{ km}^2$



Comparison between pixel sizes

## Settings (2)

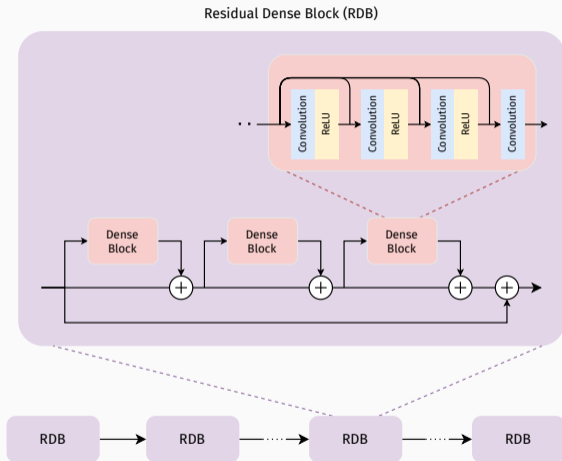
- Dataset of 1 year (2023)
- 30-70 random split for training and test
- Patches extracted from 10 polluted locations
- 2nd experiment include SRTM digital elevation data



# Model

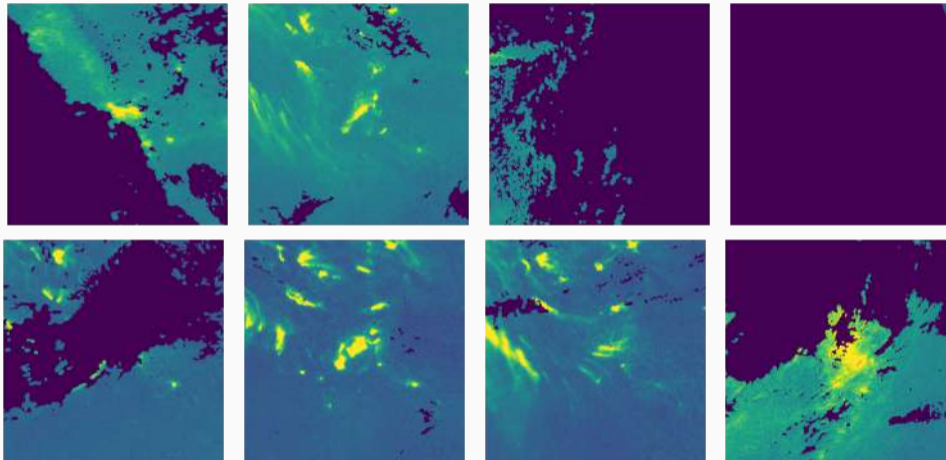
Residual Dense Super Resolution Zero Loss (RDSRZL)

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Residual in Residual Dense Network

# Missing pixels



Cloud cover averages around 67% globally

To operate with incomplete patches we modified the  $L_1$  loss (MAE) function,

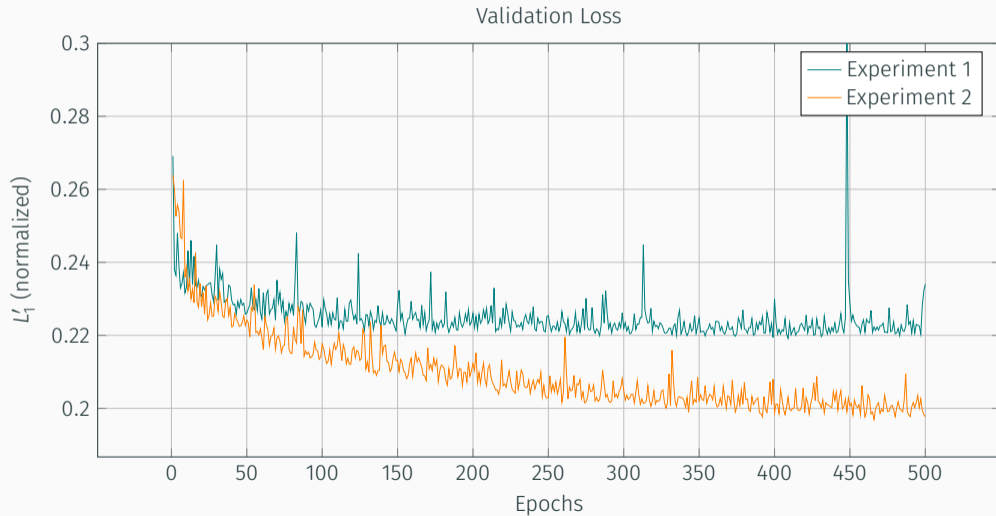
$$L'_1(y, \hat{y}) = \frac{1}{M} \sum_{i=1}^N y'_i.$$

Where,

$$y'_i = \begin{cases} |y_i - \hat{y}_i| & \text{if } m_i = 0, \\ 0 & \text{otherwise.} \end{cases}$$

Where  $m_i \in \{0, 1\}$ , called *invalidity mask*, and  $\sum_{i=0}^N m_i = M$ .

# Training





# Results

Model	Epochs	$L_1'$ (molec cm <sup>2</sup> 10 <sup>5</sup> )
Bicubic interp.	-	5.215
RDSRZL	500	3.820
RDSRZL with Elevation	500	3.701

Where the  $L_1'$  loss has been evaluated on the test set (254 days random sampled from year 2023) and averaged over the 10 selected locations.

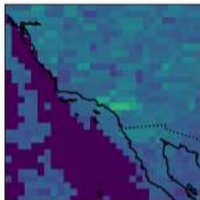
Let's look at some images

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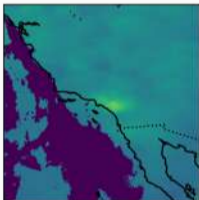
# Results (1) - With & Without Elevation



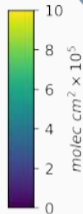
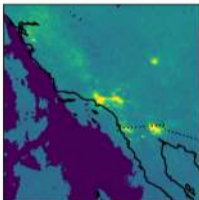
GOME-2



GOME-2 SR

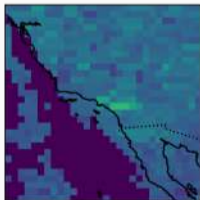


TROPOMI

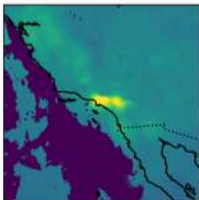


2023-08-04

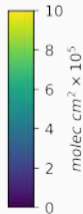
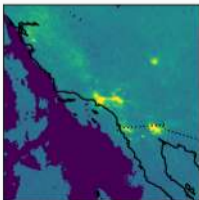
GOME-2



GOME-2 SR



TROPOMI

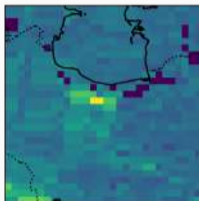


2023-08-04 Elevation

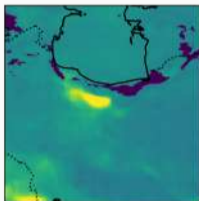
# Results (2) - Tehran



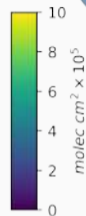
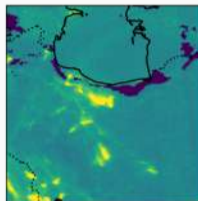
GOME-2



GOME-2 SR

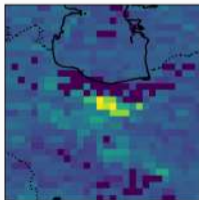


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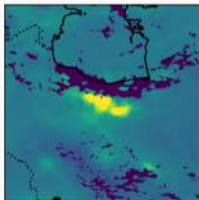


2023-07-15

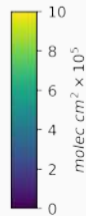
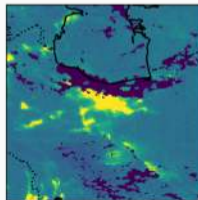
GOME-2



GOME-2 SR



TROPOMI

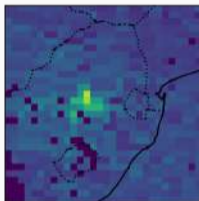


2023-10-14

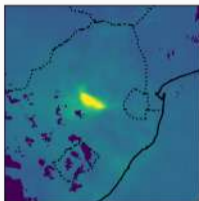
# Results (3) - Johannesburg



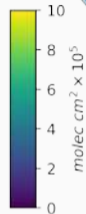
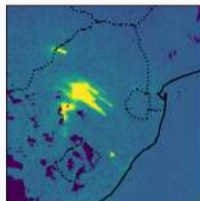
GOME-2



GOME-2 SR

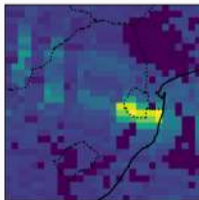


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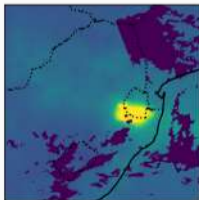


2023-01-11

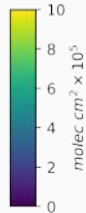
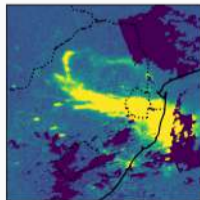
GOME-2



GOME-2 SR



TROPOMI



2023-06-21

## Future Work

- Test different neural network models (ResNet, ViT)
- Include ERA5 dataset (wind, pressure, temperature, etc.)
- Analyze performance on time series
- Analyze performance on others locations (with and without re-training)
- Test different atmospheric gases

## One more thing

Study case on location out of training dataset

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# Mount Carmel Forest Fire

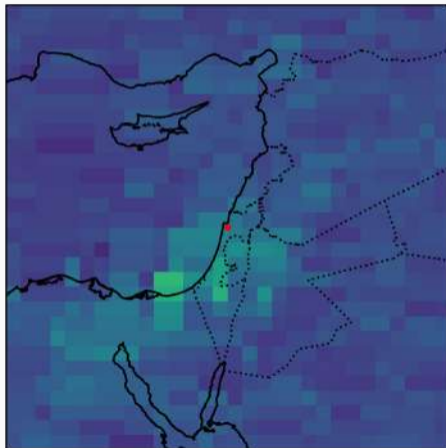


The Mount Carmel Forest Fire was a 50km<sup>2</sup> forest fire occurred the 2 December 2010 on northern Israel. We estimated the fire produced around **5000 tonnes** of NO<sub>2</sub>.

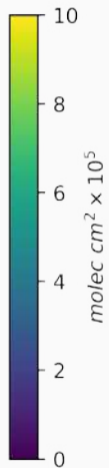
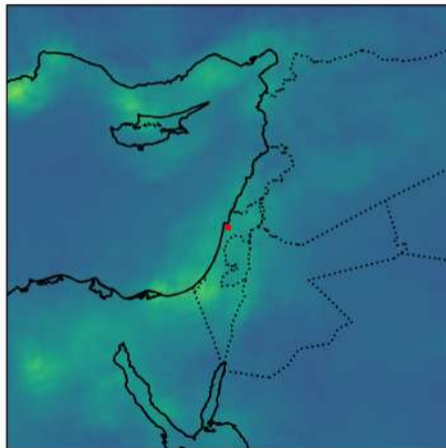


2010-11-28

GOME-2

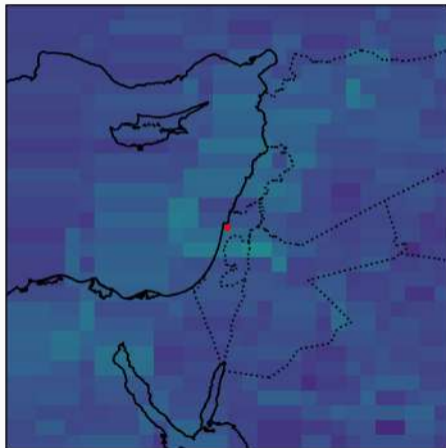


GOME-2 SR

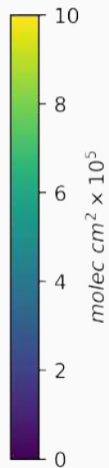
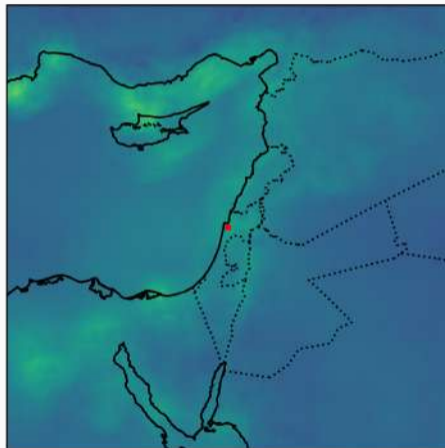


2010-11-29

GOME-2

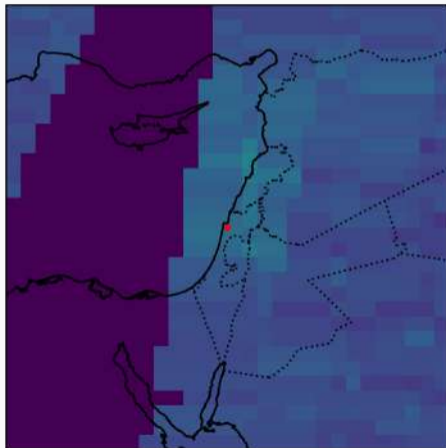


GOME-2 SR

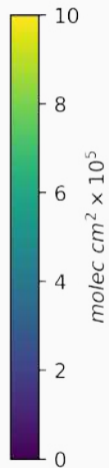
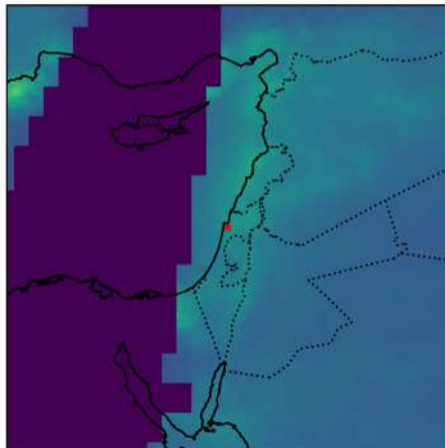


2010-11-30

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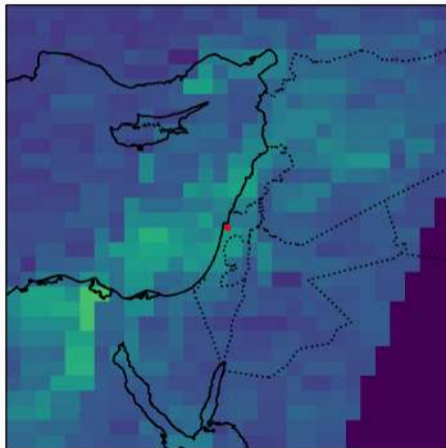


GOME-2 SR

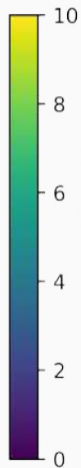
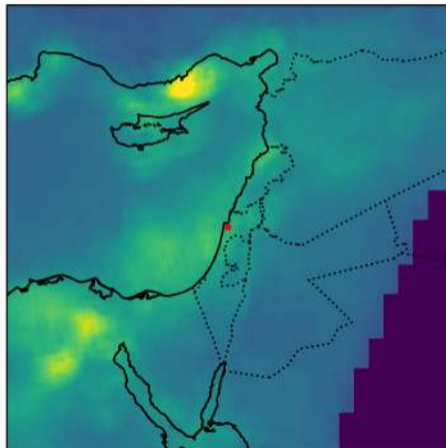


2010-12-02

GOME-2

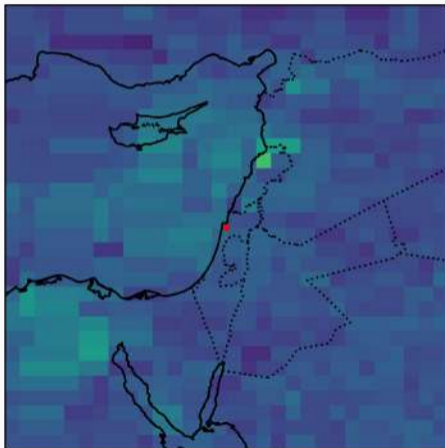


GOME-2 SR

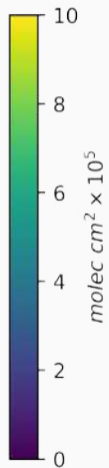
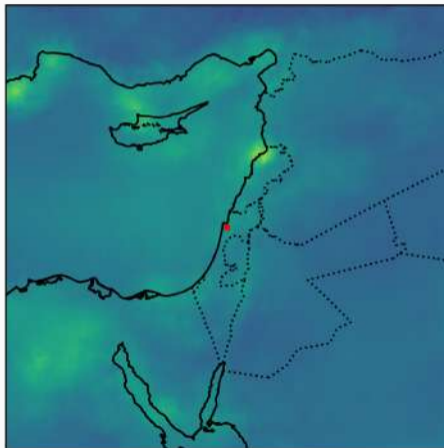


2010-12-03

GOME-2

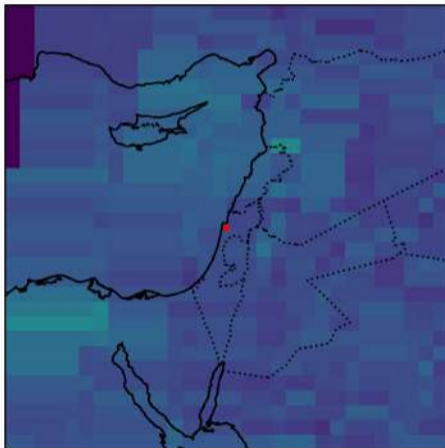


GOME-2 SR

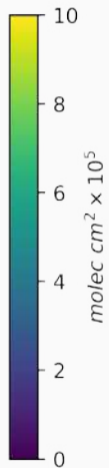
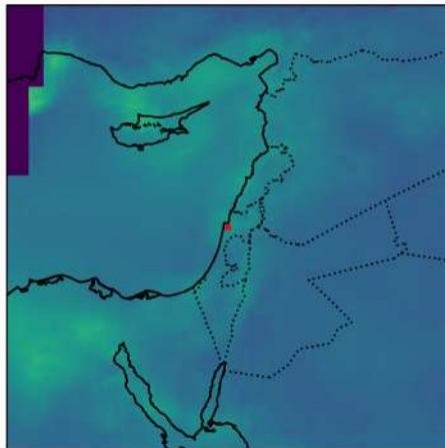


2010-12-04

GOME-2



GOME-2 SR



Thank you!

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