Enhancing BVOC Emission through Super-Resolution Techniques

Antonio Giganti, Sara Mandelli, Paolo Bestagini, Marco Marcon, Stefano Tubaro

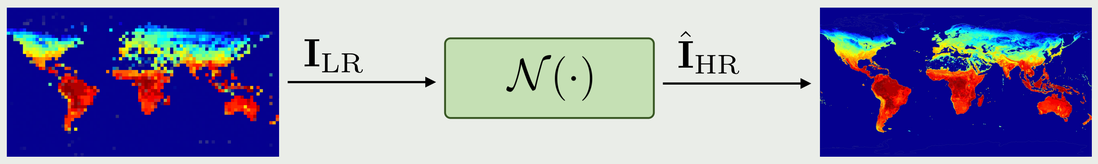
Dipartimento di Elettronica, Informazione e Bioingegneria - Politecnico di Milano – Milan, Italy

ISPL Image and Sound Processing Lab

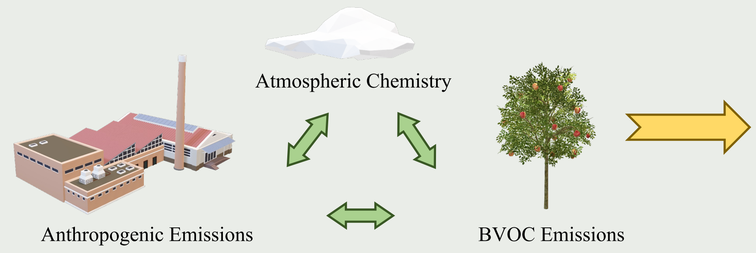
POLITECNICO MILANO 1863

Objective

BVOC Emission Super-Resolution

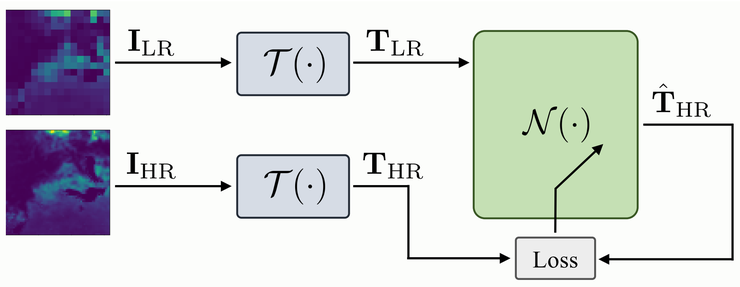


BVOC



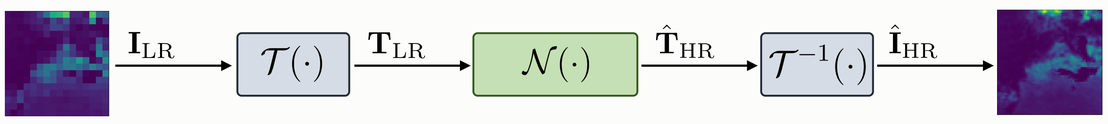
Single-Emission SR [1]

System



Training

Deployment



Solving a Realistic Scenario

CAMS-GLOB-BIO Dataset [4]

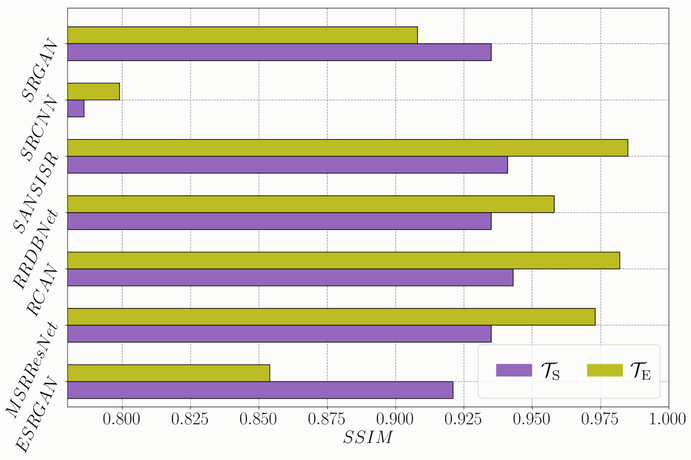
- Spatial Resolution → 0.25° × 0.25°
- Spatial Coverage → Global
- Temporal Resolution → Monthly averaged hourly profile
- Temporal Coverage → 2000 – 2019

Dataset Subsets

- $\mathcal{D}$ → Full spatial and temporal coverage
- $\mathcal{D}_T$ → Limited temporal coverage
- $\mathcal{D}_{TA}$ → Limited temporal and spatial coverage

	SANSISR	RCAN	MSRResNet
Dataset	SSIM / NMSE [dB]	SSIM / NMSE [dB]	SSIM / NMSE [dB]
$\mathcal{D}$	0.984 / −19.35	0.982 / −19.26	0.970 / −17.27
$\mathcal{D}_T$	0.986 / −21.50	0.985 / −20.44	0.973 / −17.66
$\mathcal{D}_{TA}$	0.769 / −7.31	0.774 / −7.32	0.788 / −7.26

Network Selection

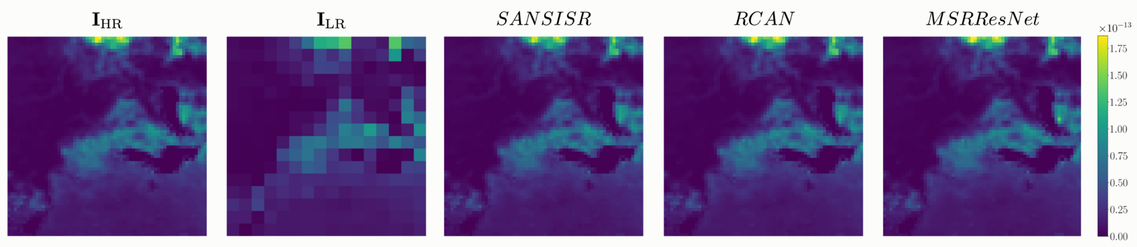


Data Transformations

- $\mathcal{T}_{\mathrm{S}}$ – *Emission Scaling*: dividing $\mathbf{I}_{\mathrm{HR}}$ and $\mathbf{I}_{\mathrm{LR}}$ by their maximum
- $\mathcal{T}_{\mathrm{E}}$ – *Emission Equalization*: re-mapping $\mathbf{I}_{\mathrm{HR}}$ and $\mathbf{I}_{\mathrm{LR}}$ with a non-parametric transformation into a uniform distribution with values between 0 and 1

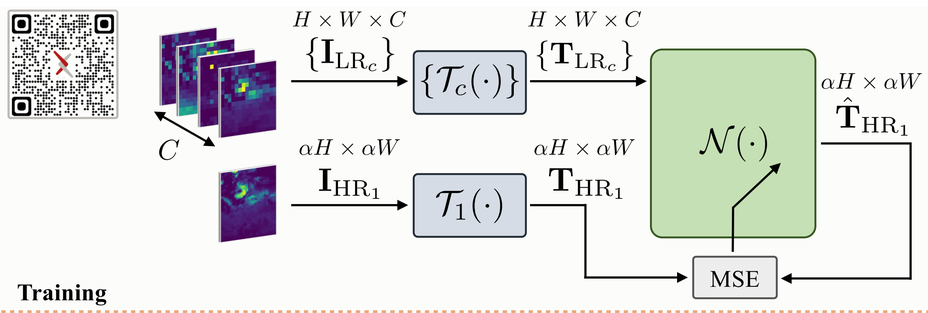
Experiment Setup

LR maps → 1° × 1° spatial resolution
HR maps → 0.25° × 0.25° spatial resolution
Scale factor (α) → 4



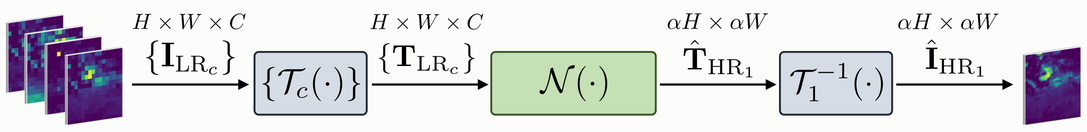
Multi-Emission SR [2]

System



Training

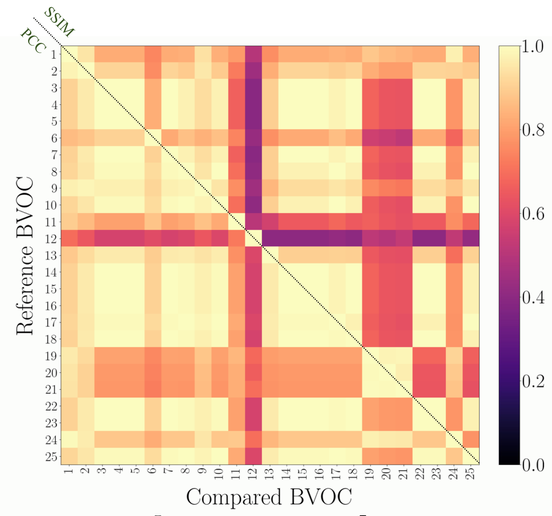
Deployment



Experimental Results

Dataset	$C=1$ SSIM / NMSE [dB]	$C=2$ SSIM / NMSE [dB]	$C=3$ SSIM / NMSE [dB]	$C=4$ SSIM / NMSE [dB]
$\mathcal{D}_{\mathrm{single}}$	0.984 / −19.35	—	—	—
$\mathcal{D}_{\mathrm{con}}$	—	1st 0.988 / −21.38 2nd 0.986 / −20.92	0.987 / −20.45	0.986 / −20.79
$\mathcal{D}_{\mathrm{unc}}$	—	1st 0.988 / −21.09 2nd 0.987 / −21.31	**0.989 / −21.93**	0.986 / −20.51

BVOCs Inter-connection



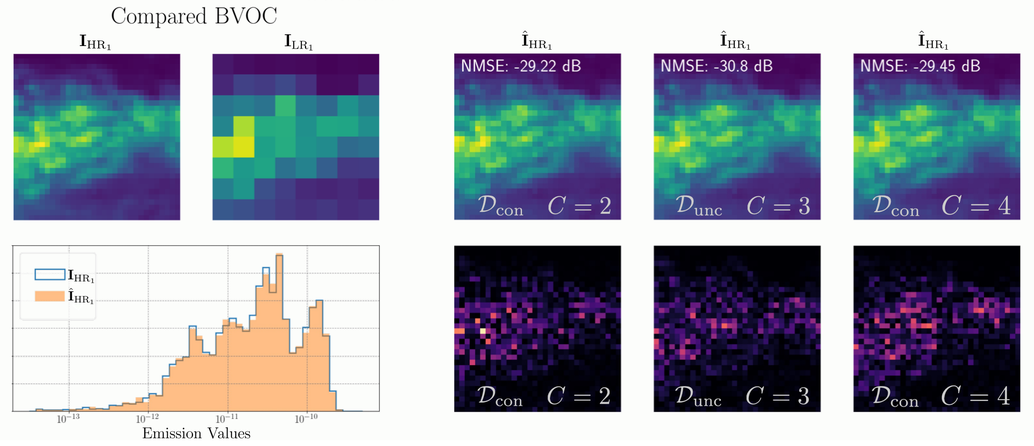
Results w.r.to Isoprene

3 ***best*** inter-connected compounds

- *Acetaldehyde*
- *Sesquiterpenes*
- *Formaldehyde*

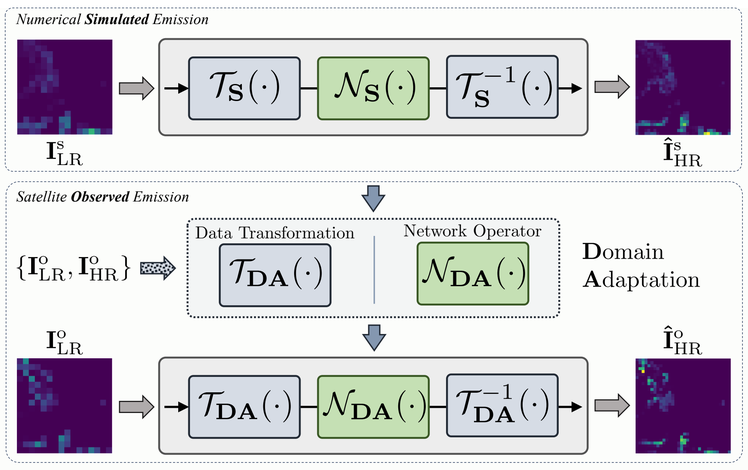
3 ***less*** inter-connected compounds

- *MBO*
- *Methanol*
- *β-pinene*

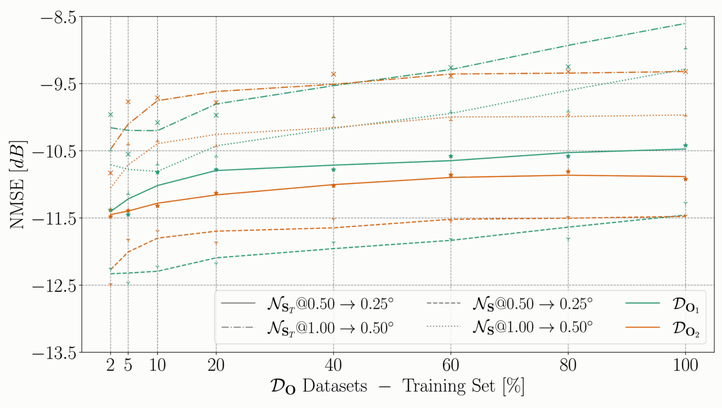


Satellite-Observed Emission SR [3]

System

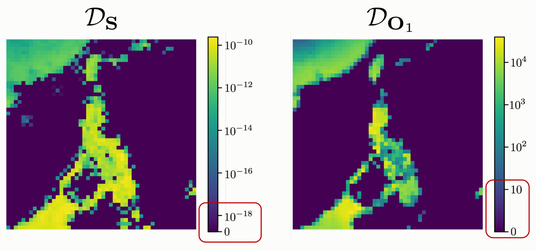


Data Transformation Adaptation

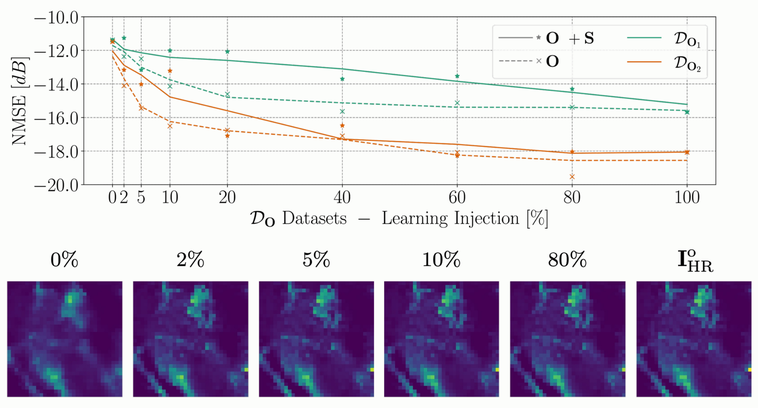


Emission Inventories

1) **CAMS-GLOB-BIO ($\mathcal{D}_{\mathbf{S}}$)** [4]
2) **GOME-2 ($\mathcal{D}_{\mathbf{O}_1}$)** [5] and **OMI ($\mathcal{D}_{\mathbf{O}_2}$)** [6]
   - Spatial Resolution → 0.50° × 0.50°
   - Spatial Coverage → Global
   - Temp. Resolution → Daily averaged
   - Temp. Cov. (int.) → 2007 – 2012



Network Operator Adaptation



Perfect Knowledge Results

Dataset	Spatial Resolution	No.Patches	NMSE [dB]	SSIM	Training Time [%]
$\mathcal{D}_{\mathbf{S}}$	0.50° → 0.25°	630192	−23.83	0.988	100 [ref]
	1.00° → 0.50°	73152	−19.40	0.988	17.60
$\mathcal{D}_{\mathbf{S}_T}$	0.50° → 0.25°	187488	−26.54	0.989	23.15
	1.00° → 0.50°	21864	−22.33	0.989	10.32
$\mathcal{D}_{\mathbf{O}_1}$	1.00° → 0.50°	16495	−15.68	0.979	3.73
$\mathcal{D}_{\mathbf{O}_2}$	1.00° → 0.50°	16495	−18.07	0.977	3.73

References

[1] Giganti, A., *et al.* (2023). *Super-Resolution of BVOC Maps by Adapting Deep Learning Methods*. ICIP
[2] Giganti, A., *et al.* (2023). *Multi-BVOC Super-Resolution Exploiting Compounds Inter-Connection*. EUSIPCO
[3] Giganti, A., *et al.* (2023). *Super-Resolution of BVOC Emission Maps Via Domain Adaptation*. IGARSS
[4] Sindelarova, K., *et al.* (2022). *High-Resolution Biogenic Global Emission Inventory for the Time Period 2000–2019 for Air Quality Modelling*. Copernicus EGU
[5] De Smedt, I., *et al.* (2012). *Improved Retrieval of Global Tropospheric Formaldehyde Columns from GOME-2/MetOp-A Addressing Noise Reduction and Instrumental Degradation Issues*. Copernicus EGU
[6] Bauwens, M., *et al.* (2016). *Nine Years of Global Hydrocarbon Emissions Based on Source Inversion of OMI Formaldehyde Observations*. Copernicus EGU

Acknowledgment

This work was supported by the Italian Ministry of University and Research (MUR) and the European Union (EU) under the PON/REACT project.

PON RICERCA E INNOVAZIONE 2014 - 2020 · MUR Ministero dell'Università e della Ricerca · UNIONE EUROPEA Fondo Sociale Europeo

SCAN ME !