

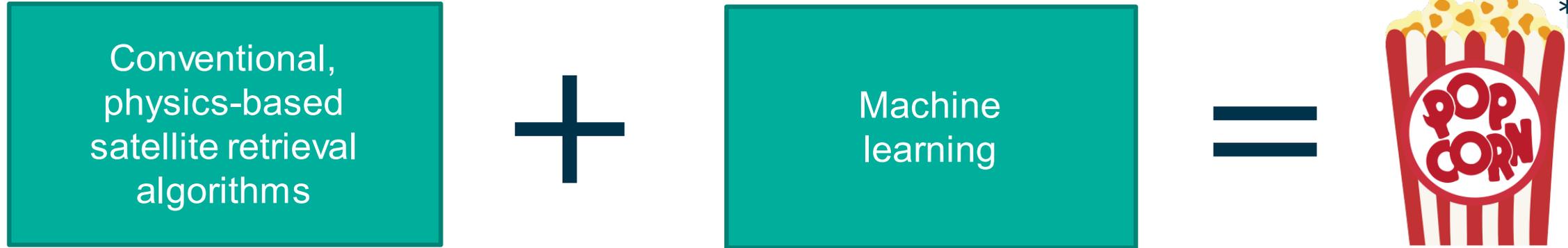
# Machine Learning-Based Post-Process Correction of the High-Resolution Multi- Wavelength Sentinel-3 Synergy Aerosol Product

Antti Lipponen<sup>1</sup>, Jaakko Reinvall<sup>2</sup>, Arttu Väisänen<sup>2</sup>, Henri Taskinen<sup>2</sup>, Timo Lähivaara<sup>2</sup>, Larisa Sogacheva<sup>1</sup>, Pekka Kolmonen<sup>1</sup>, Kari Lehtinen<sup>1,2</sup>, Antti Arola<sup>1</sup>, and Ville Kolehmainen<sup>2</sup>

*<sup>1</sup>Finnish Meteorological Institute, Finland*

*<sup>2</sup>University of Eastern Finland, Finland*

## Introduction



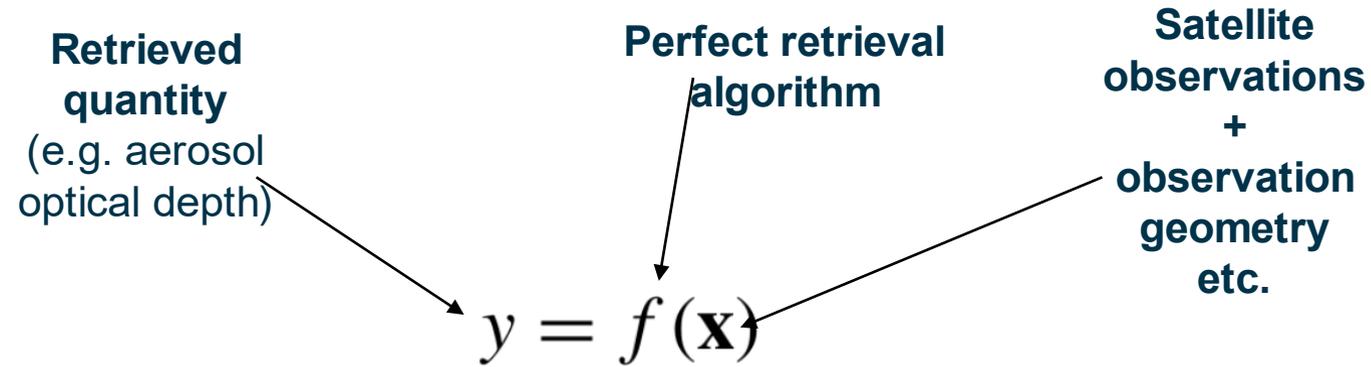
- **General approach, applicable to any satellite data product (given suitable training data)**
- **Our approach enables post-processing of existing old datasets as well**
  - No need for re-processing of huge datasets with conventional algorithms
- **Correction of parameters' accuracy and spatial anomalies**
- **Here we use S3 Synergy 300-meter resolution aerosol optical depth (AOD) of SY\_2\_SYN as our test case (use ground-based AERONET in training and validation)**

\* Post-Process Correction of Satellite Data Products with New Machine Learning Based Approach (POPCORN)

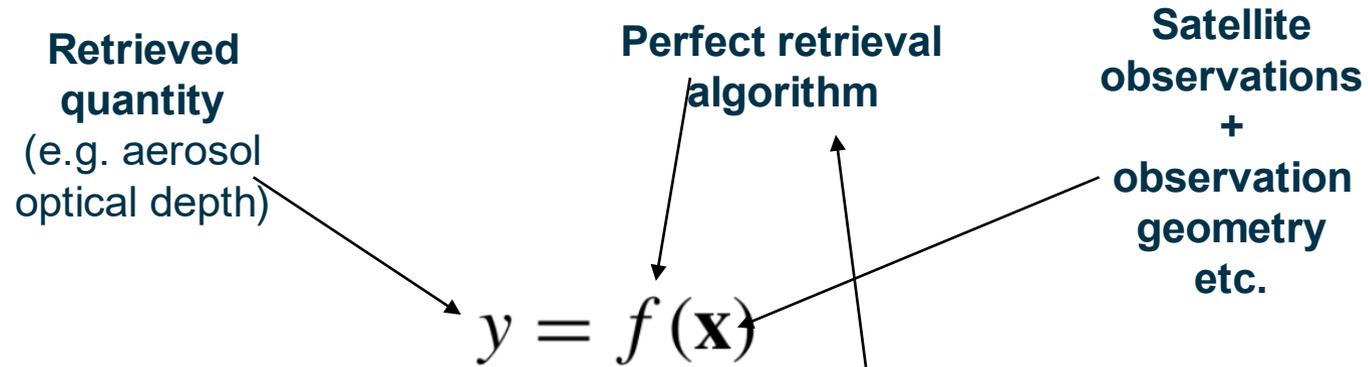
# Satellite retrievals - Models

$$y = f(\mathbf{x})$$

# Satellite retrievals - Models

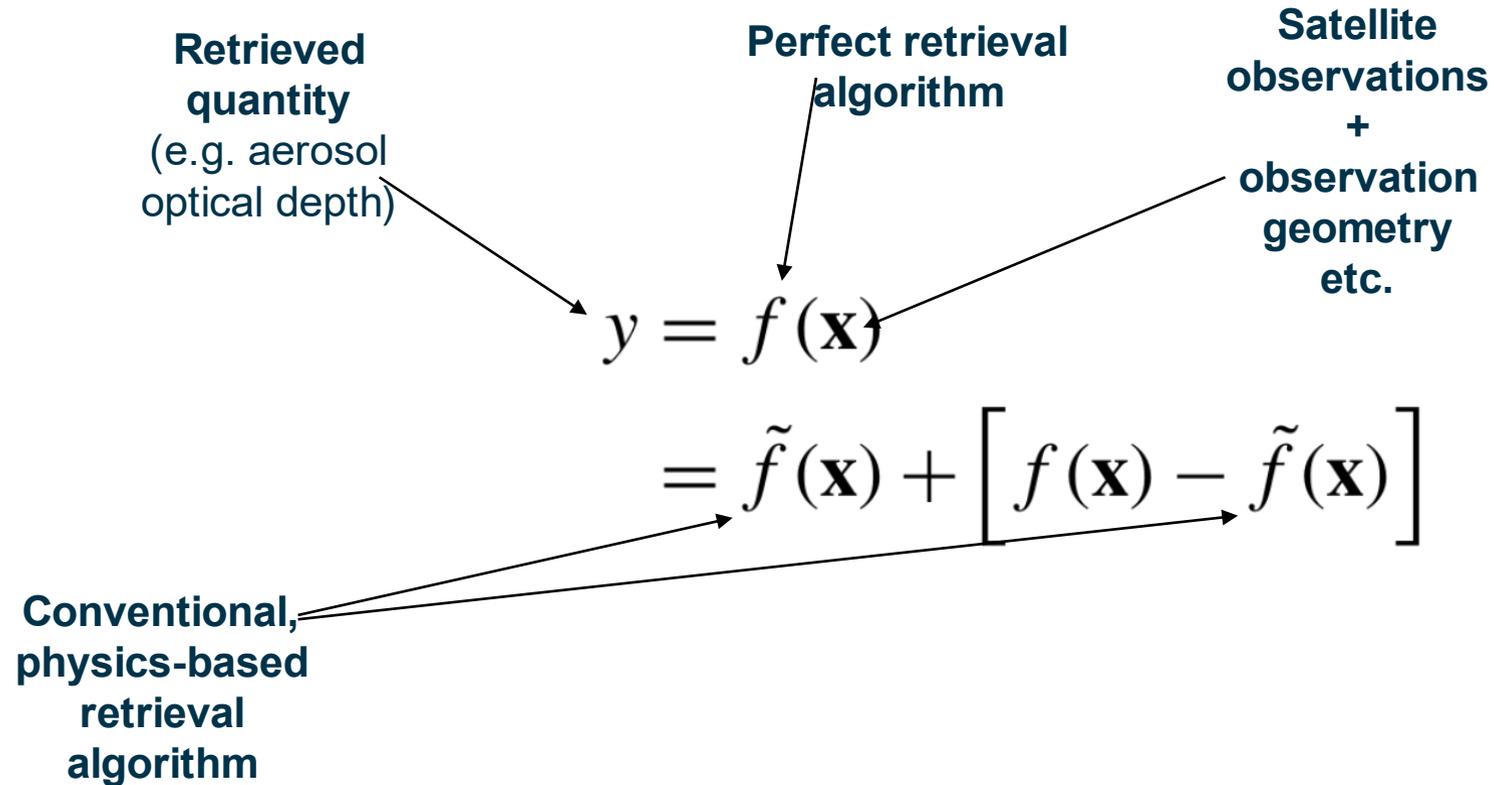


# Satellite retrievals - Models

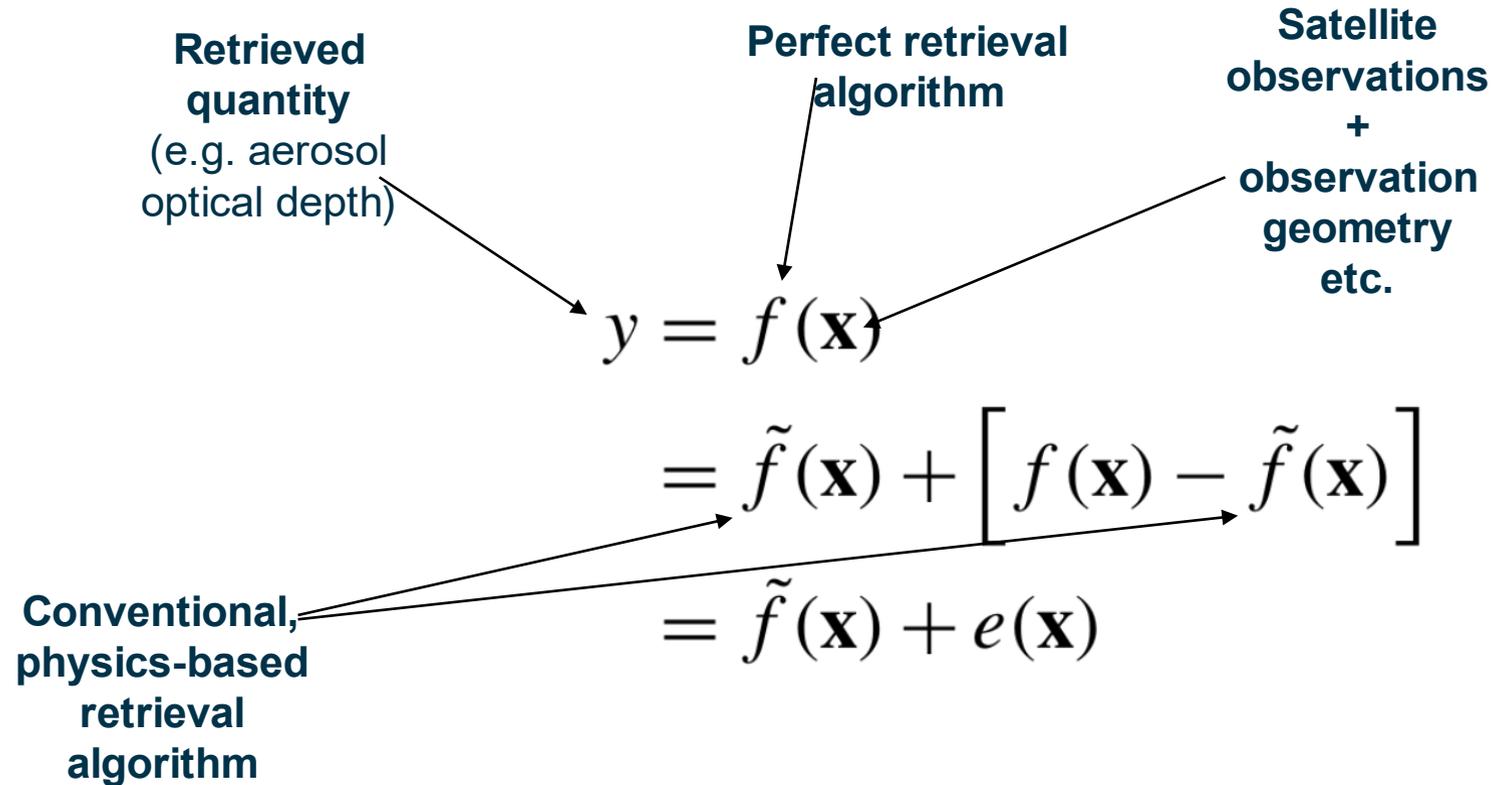


**DOES NOT EXIST  
IN REAL LIFE!**

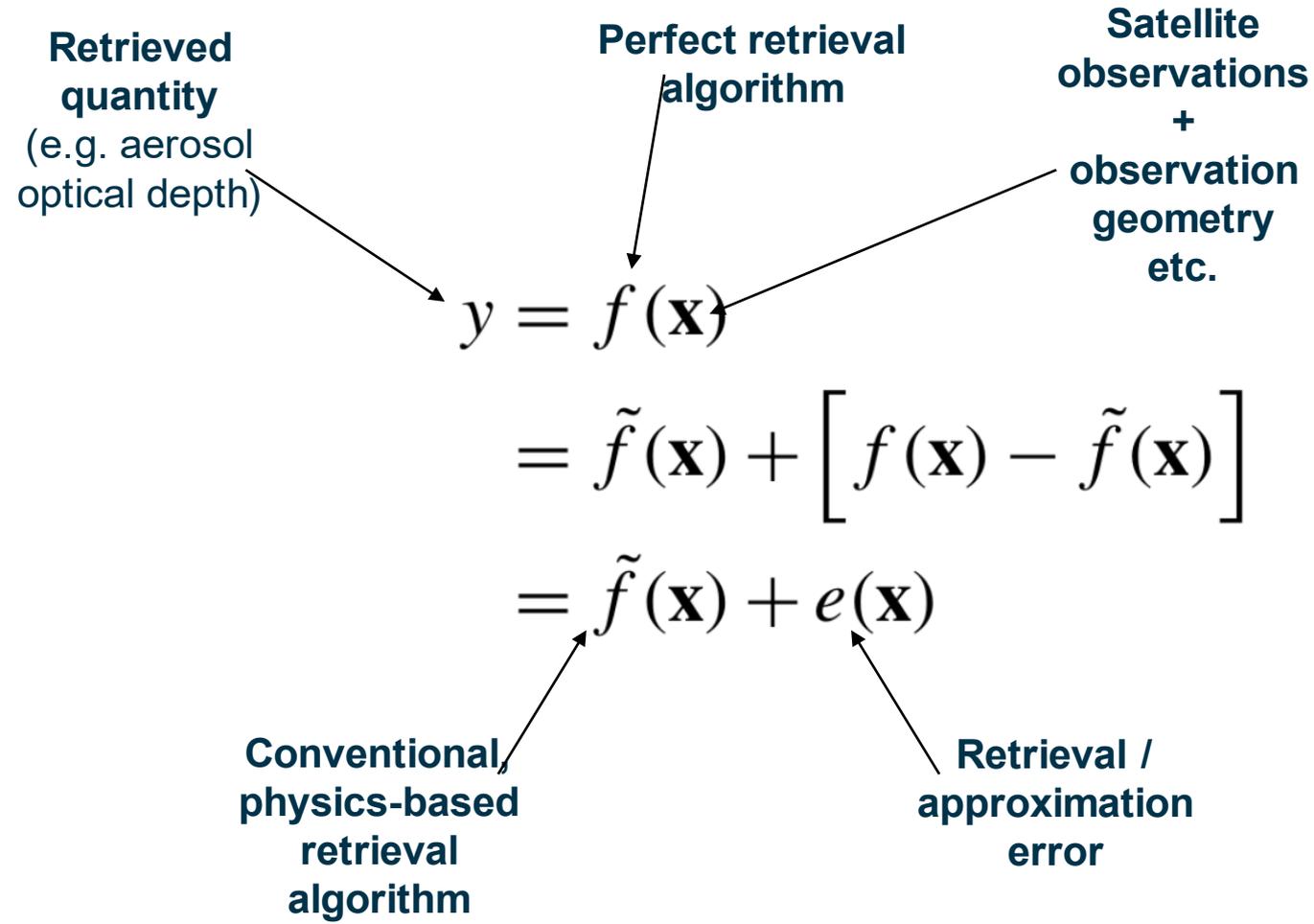
# Satellite retrievals - Models



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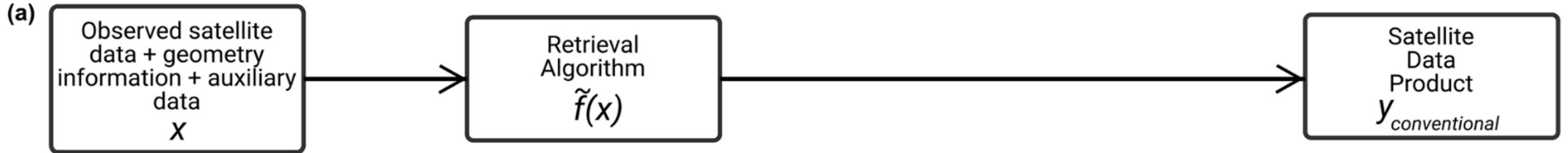


# Satellite retrievals - Models

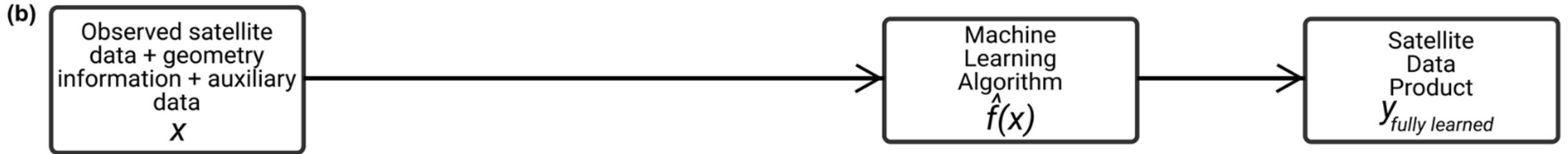


# Retrieval models

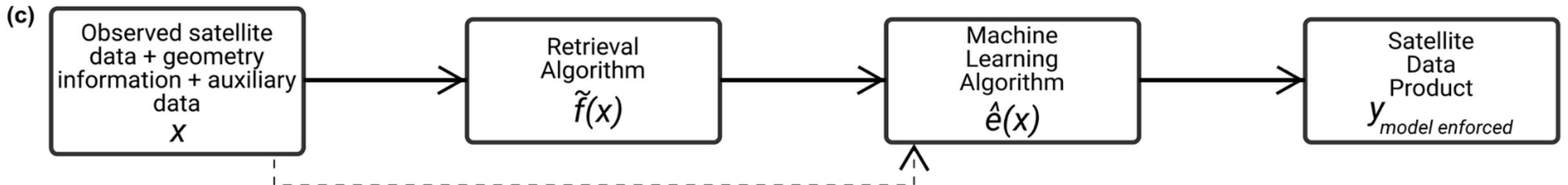
## Conventional Satellite Retrievals



## Fully Learned Satellite Retrievals



## Model Enforced Post-Process Correction of Satellite Retrievals



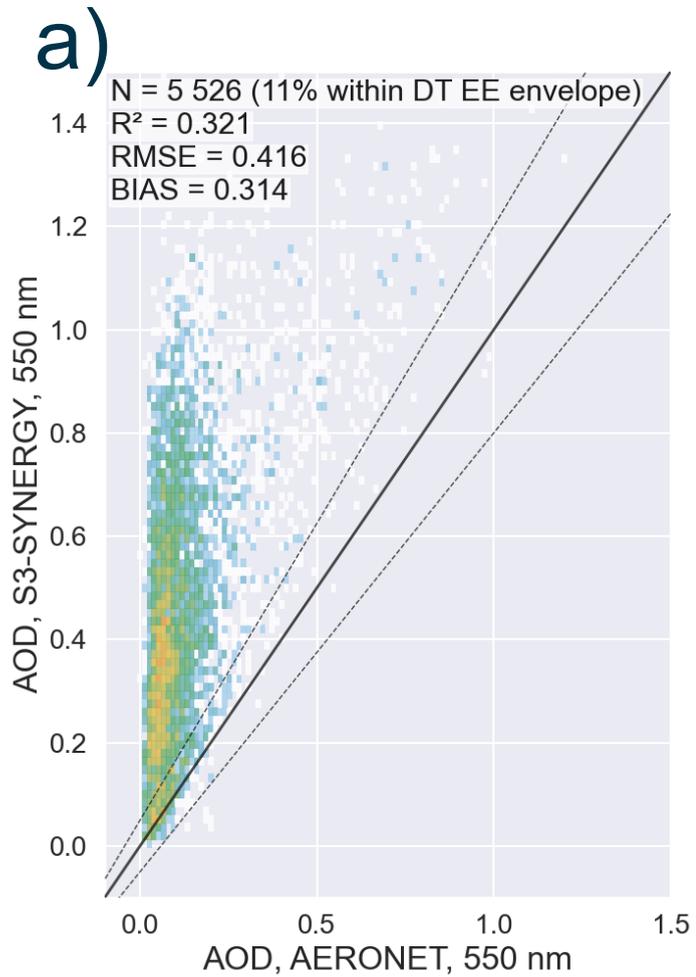
## Hypothesis:

**Prediction of the retrieval error with machine learning methods is “easier” task than the prediction of the full retrieval**

(at least with finite amount of training data)

→ **prediction of retrieval error and correction of the original retrieval results in more accurate result than the direct machine-learning-based regression**

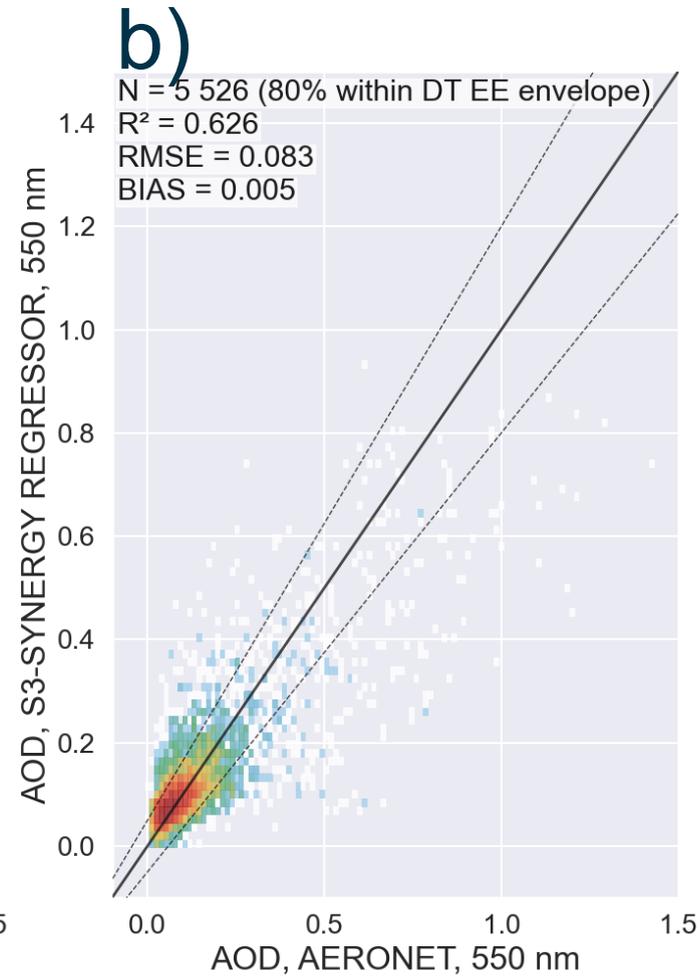
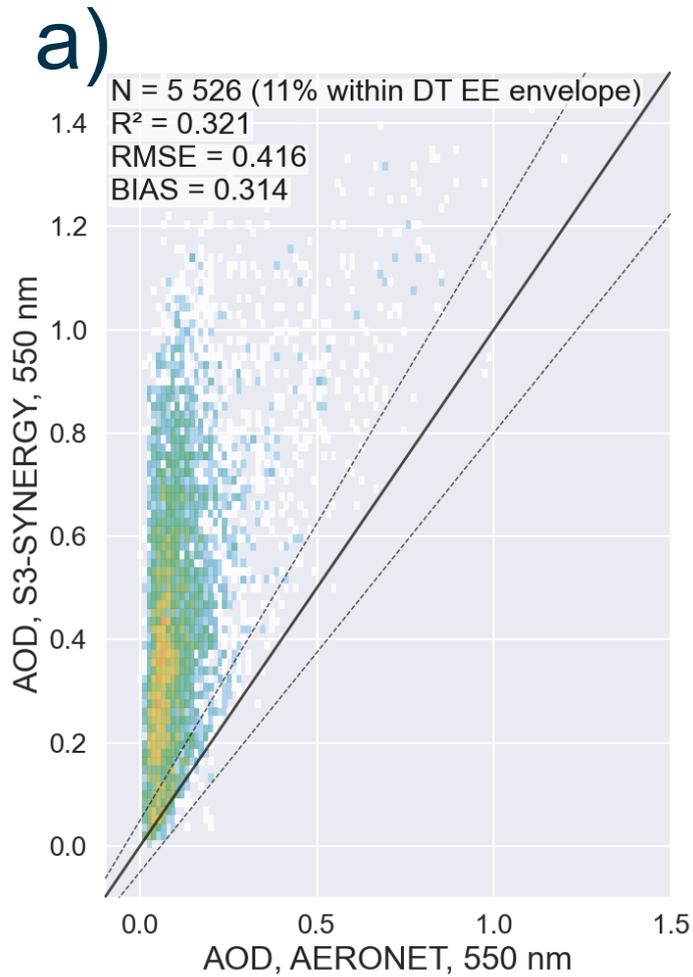
# S3 SYN (SY\_2\_SYN) Aerosol Optical Depth (AOD)



b)

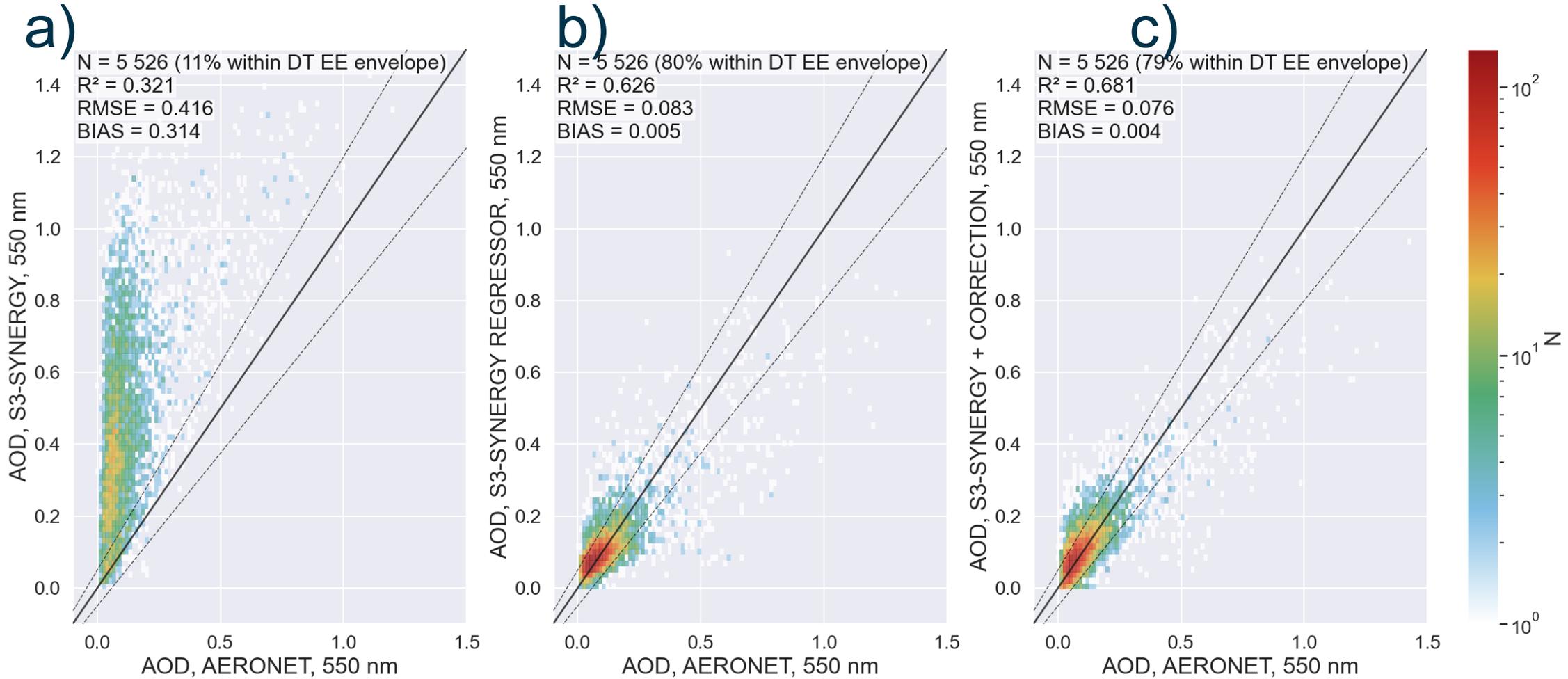
c)

# S3 SYN (SY\_2\_SYN) Aerosol Optical Depth (AOD)

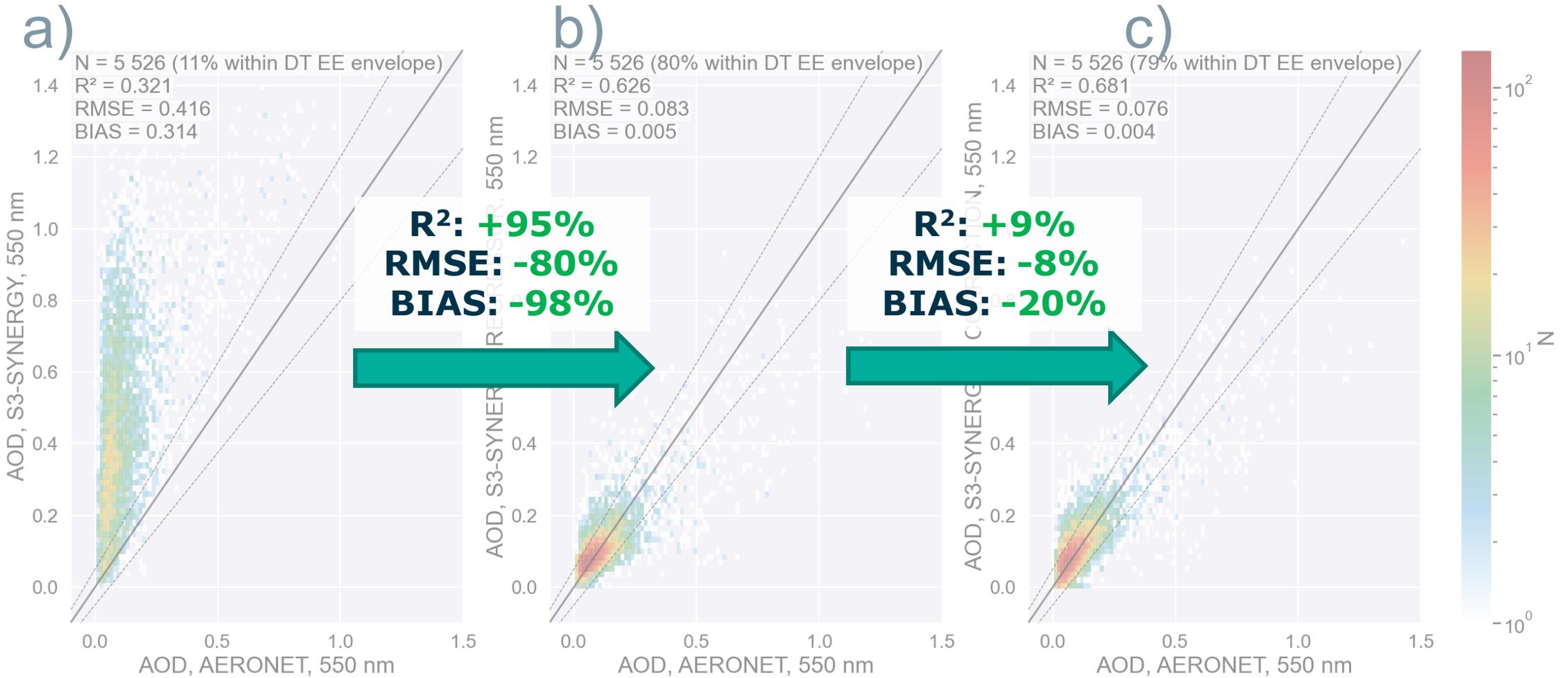


**c)**

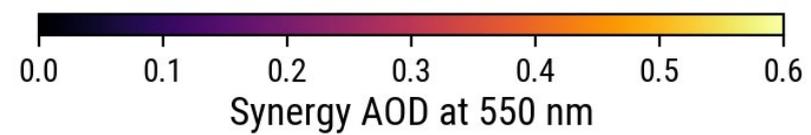
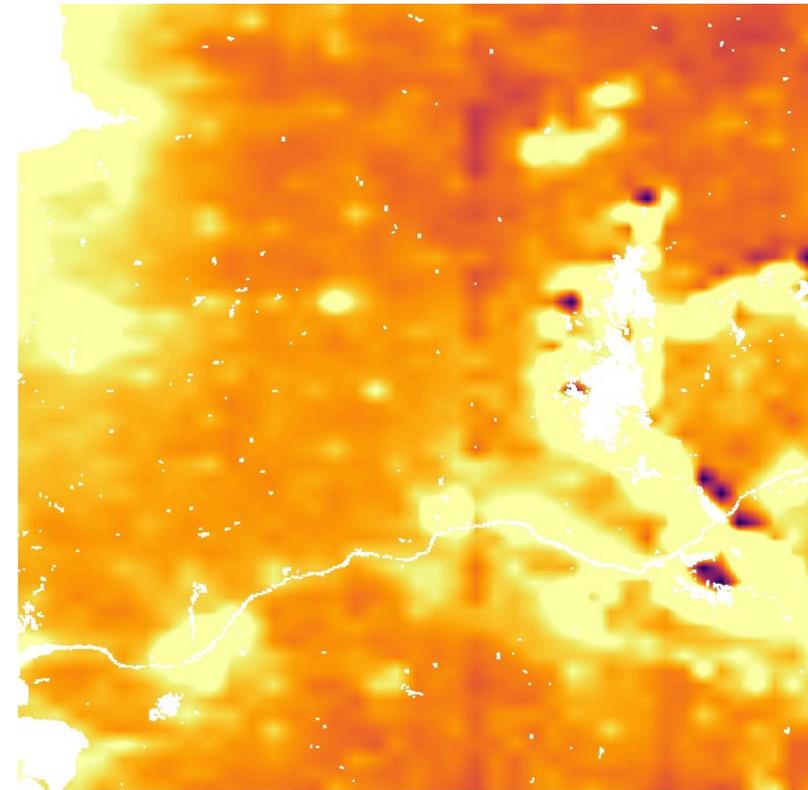
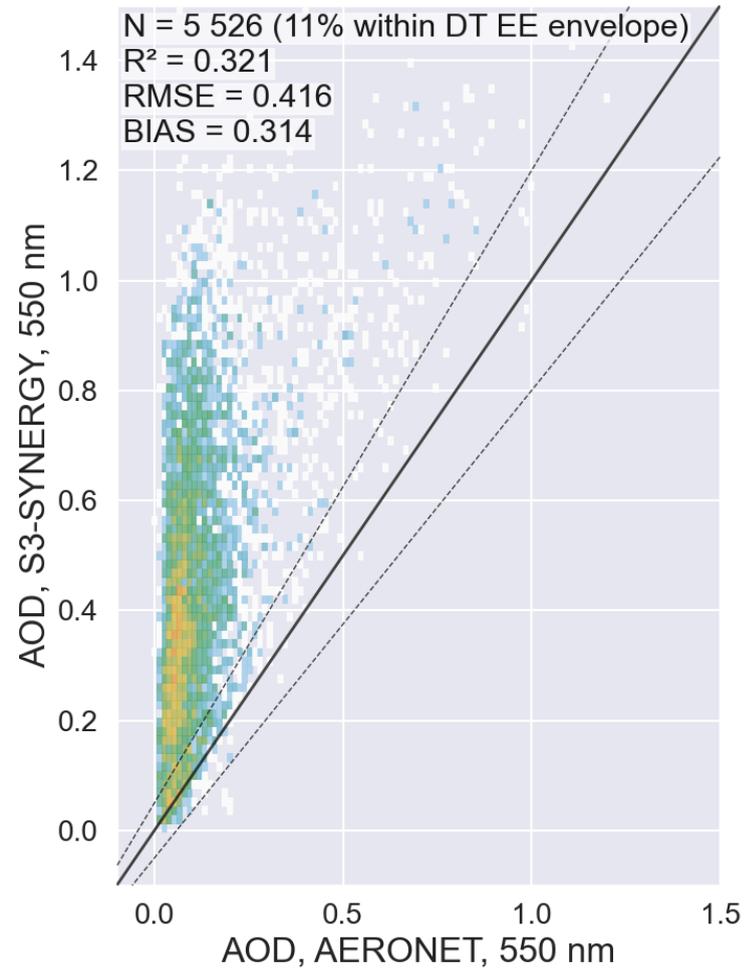
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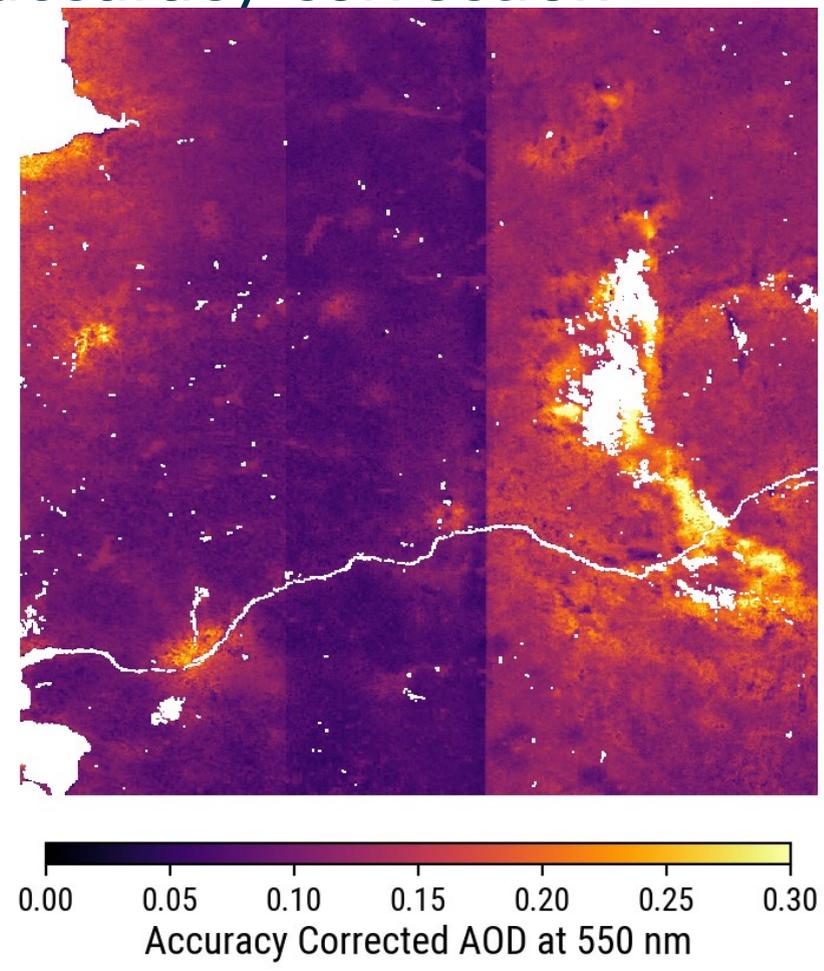
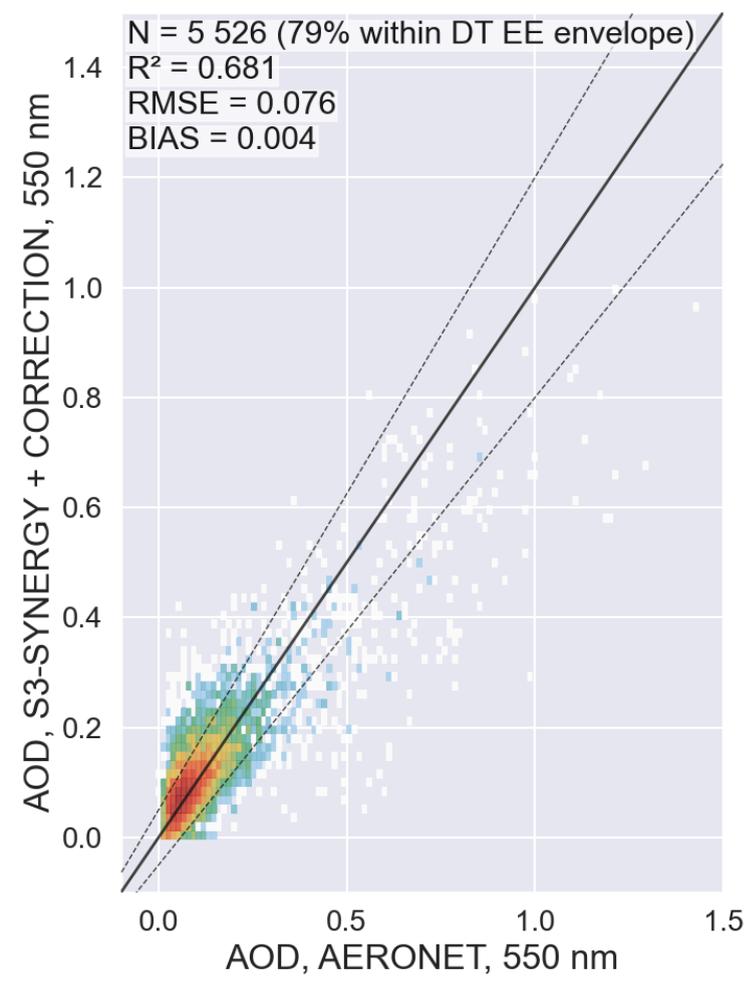


# SY\_2\_SYN aerosol parameters (AOD)



Sentinel-3A, 29 March 2019

# SY\_2\_SYN aerosol parameters (AOD) + accuracy correction



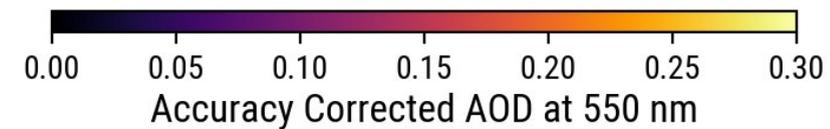
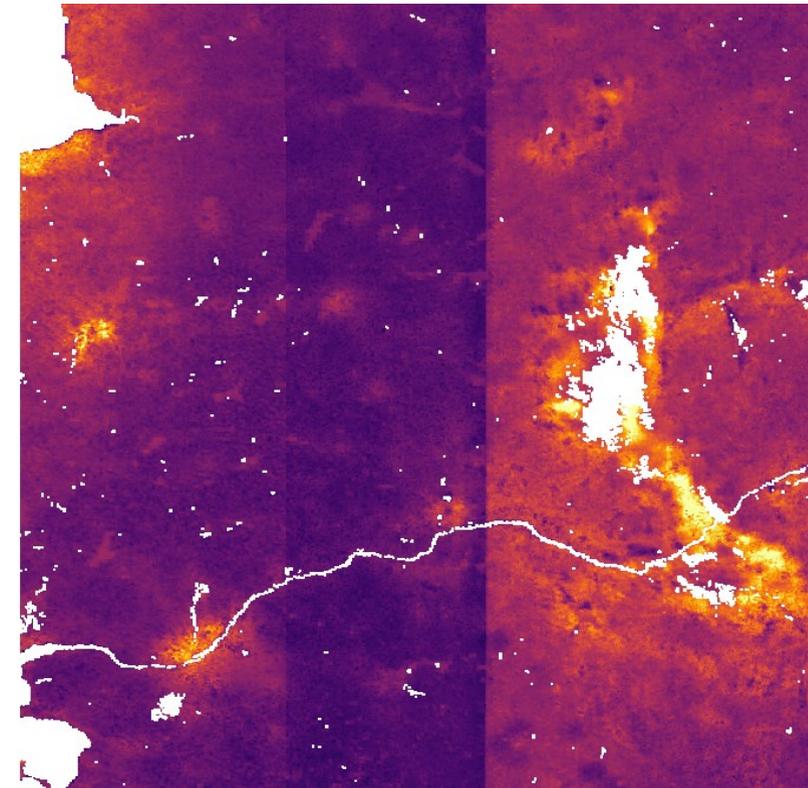
Sentinel-3A, 29 March 2019

# Correction of spatial anomalies

Machine-learning-based approach

Neural network (UNET architecture)

Trained using post-process corrected Sentinel-3 aerosol parameter data and artificially generated spatial anomalies



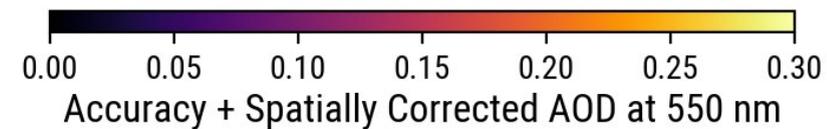
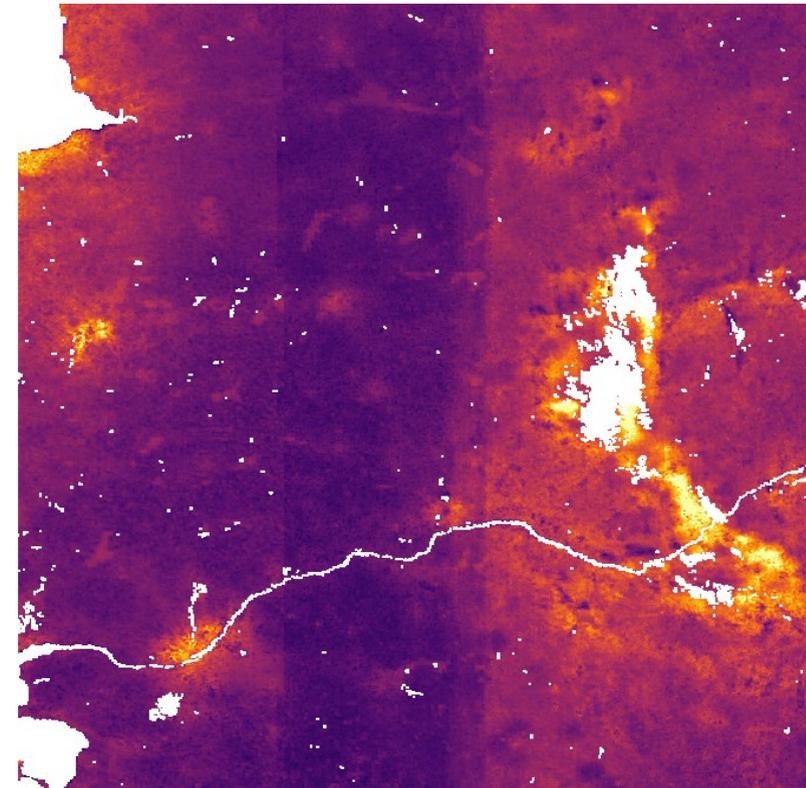
Sentinel-3A, 29 March 2019

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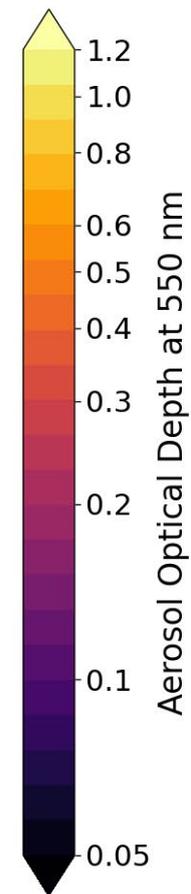
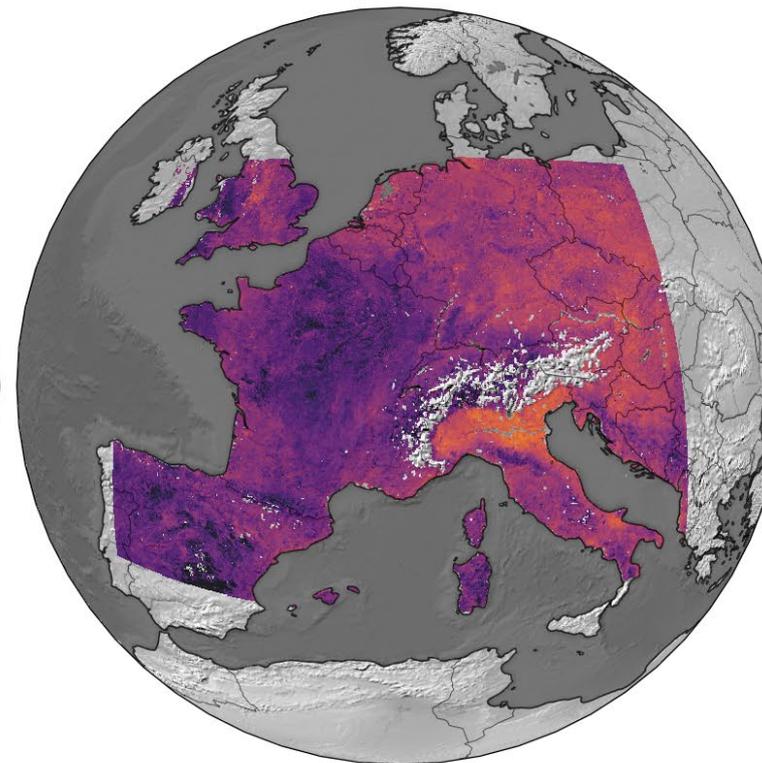
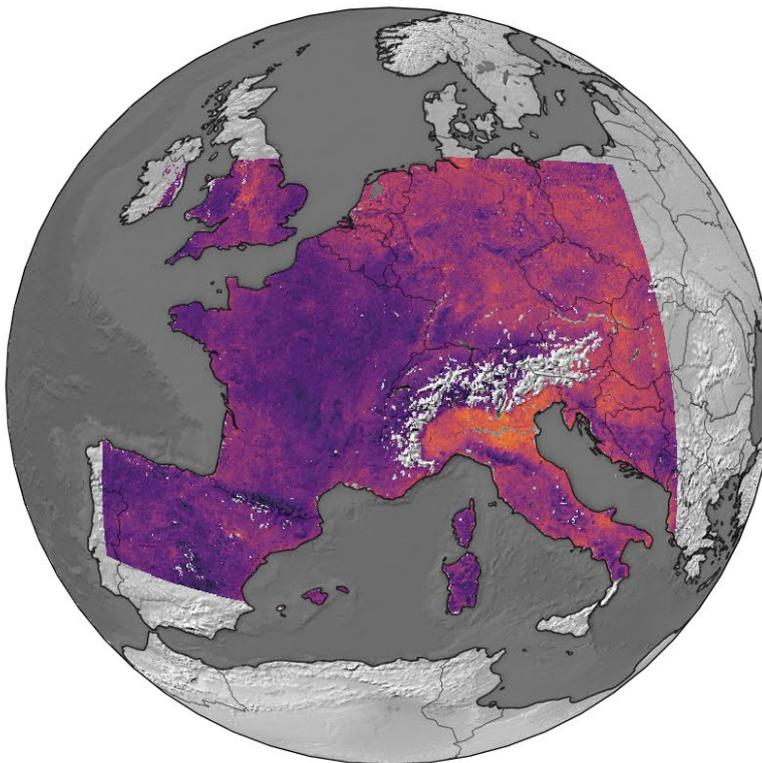
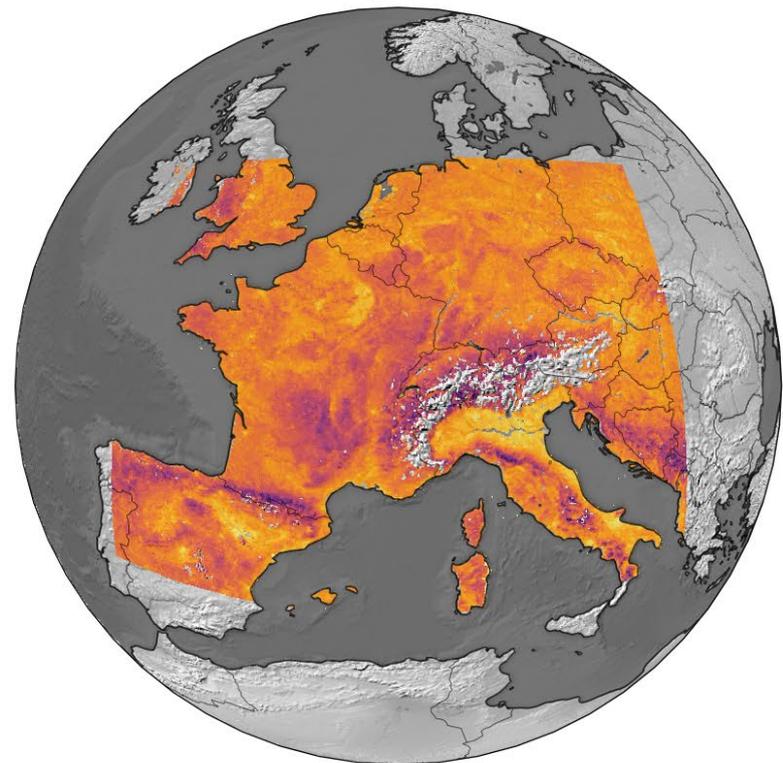
Sentinel-3A, 29 March 2019

# Aerosol optical depth at 550 nm, late August 2019

SYN

REGR.

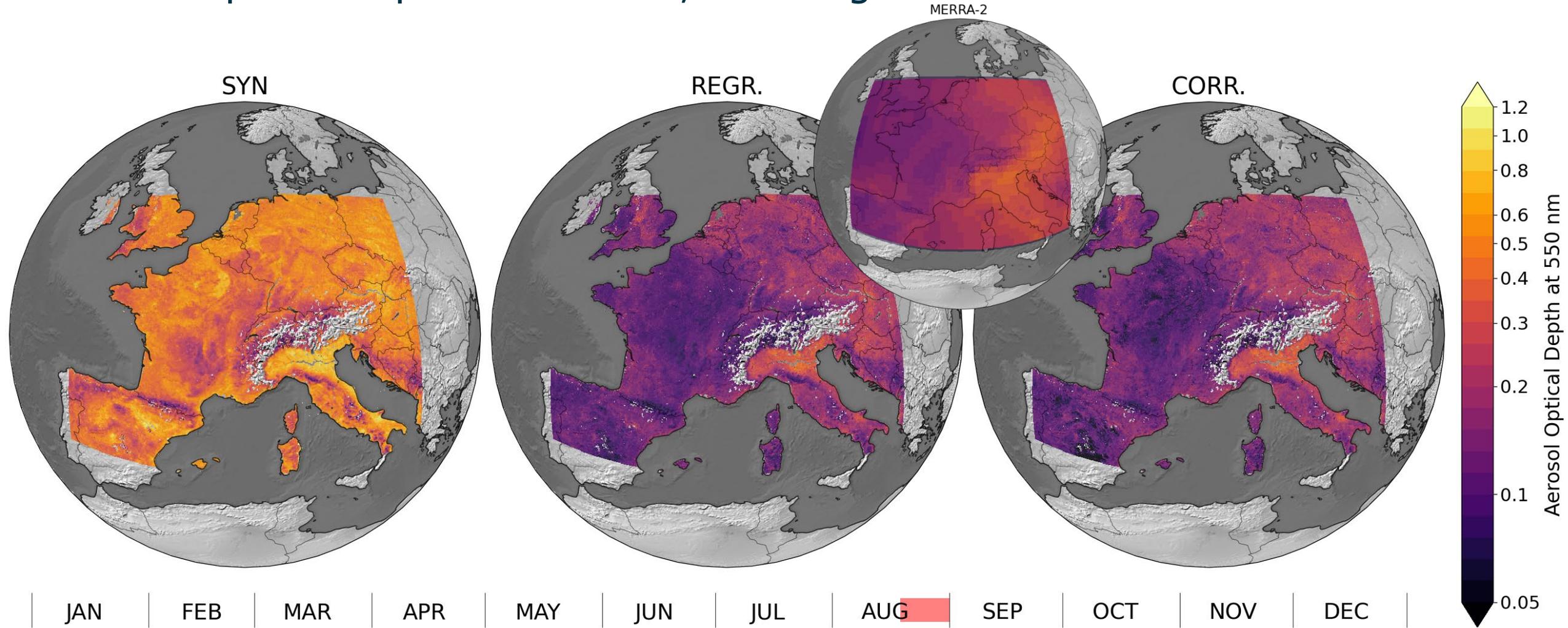
CORR.



JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC



# Aerosol optical depth at 550 nm, late August 2019

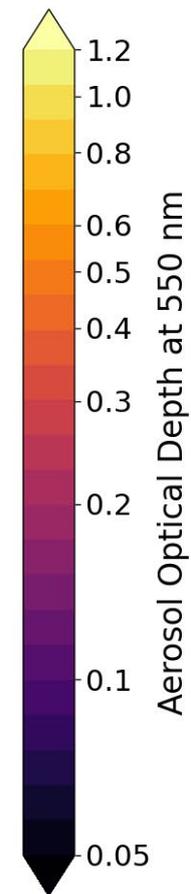
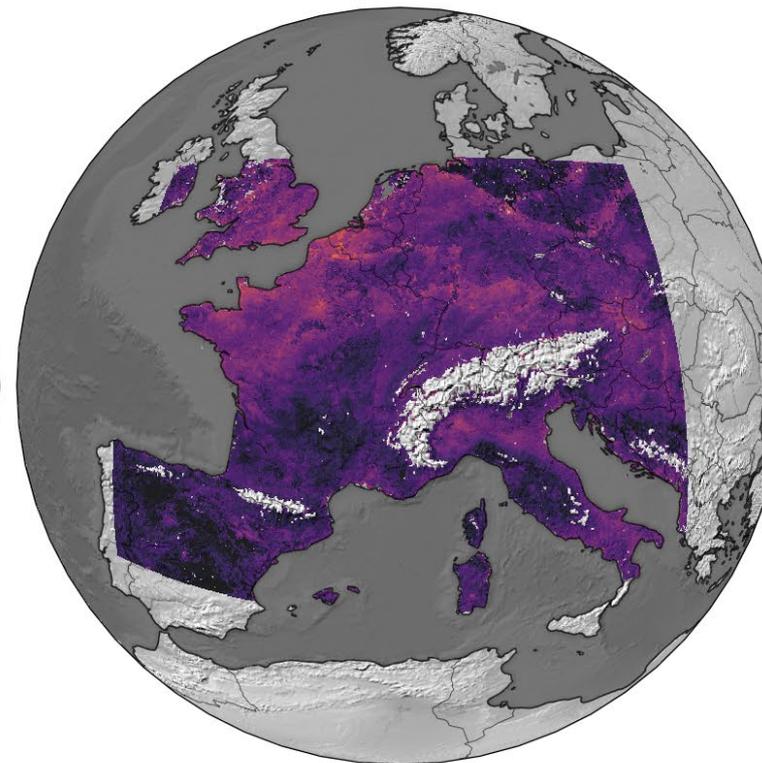
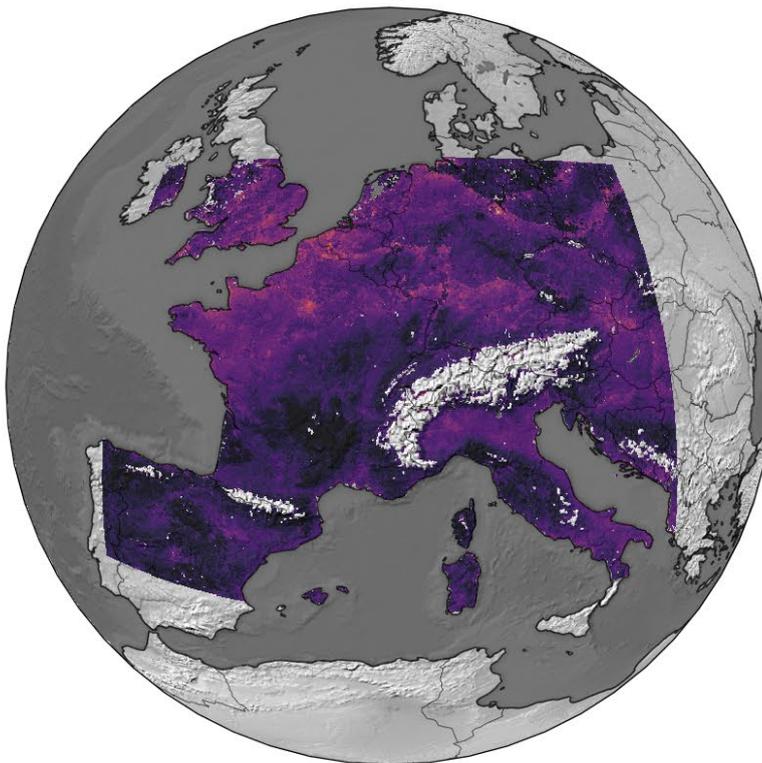
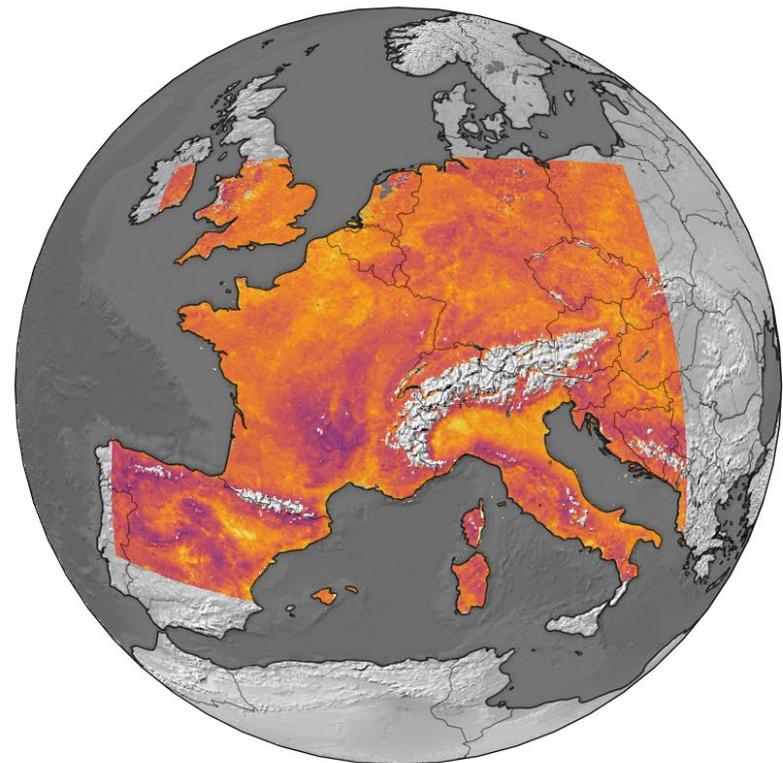


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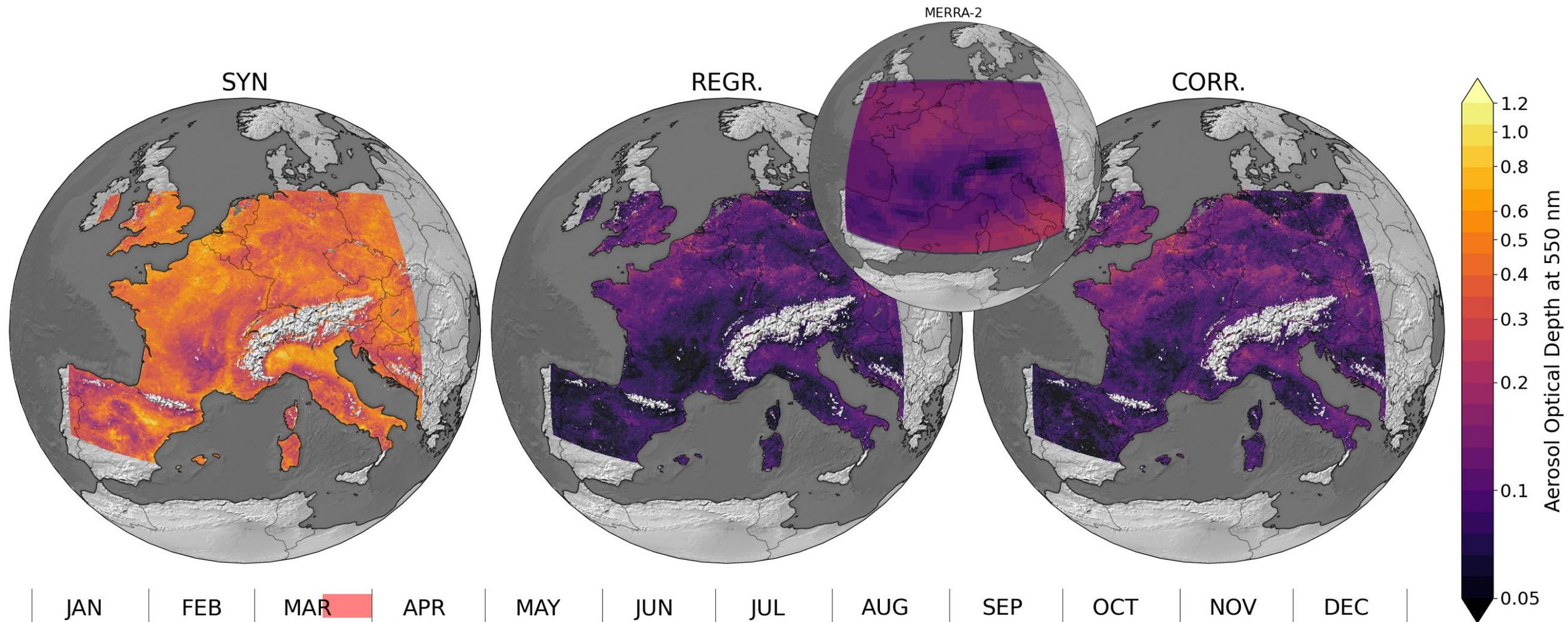
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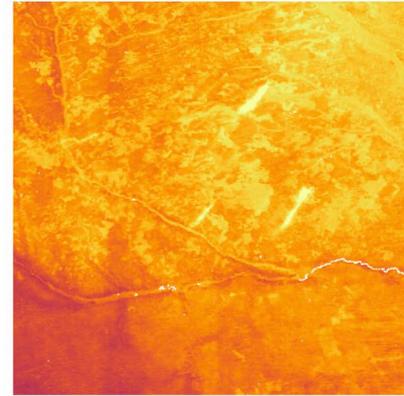
# Southern Africa wildfire smoke example

S3A, Sep 4, 2019



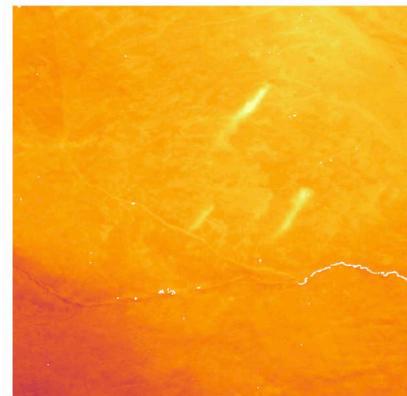
0.01 0.10 1.00  
Synergy AOD at 550 nm

Sentinel-3A, 4 September 2019



0.01 0.10 1.00  
Fully learned AOD at 550 nm

Sentinel-3A, 4 September 2019



0.01 0.10 1.00  
Corrected AOD at 550 nm

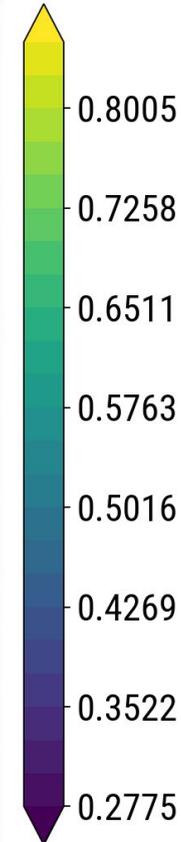
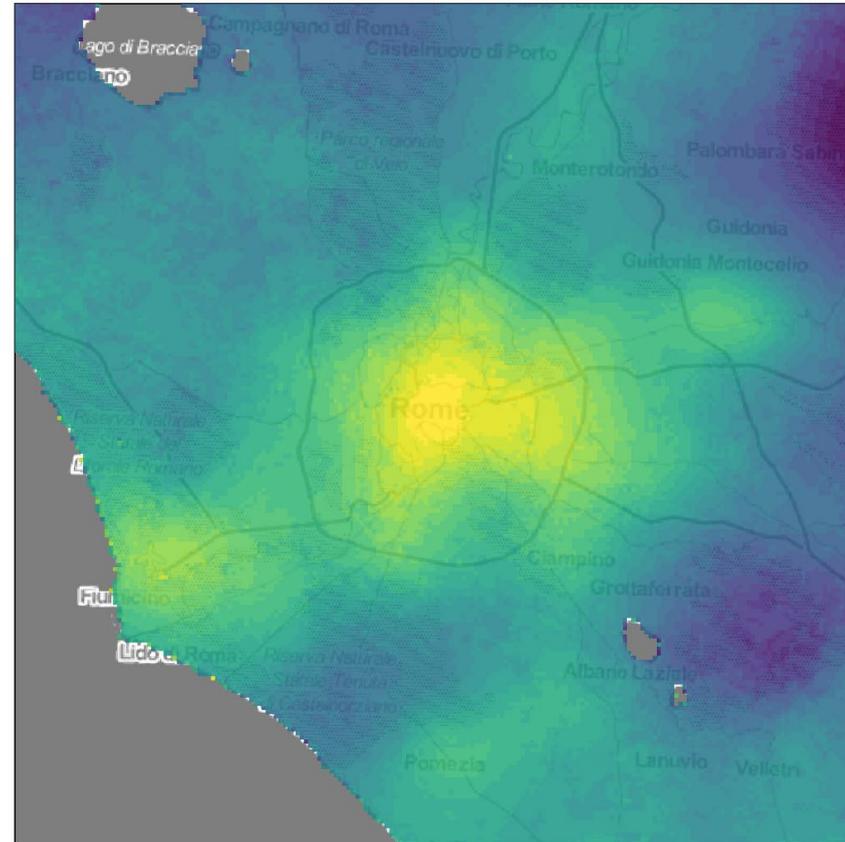
Sentinel-3A, 4 September 2019

# Rome, Italy

# Average AOD for July 2019

Synergy AOD

Rome



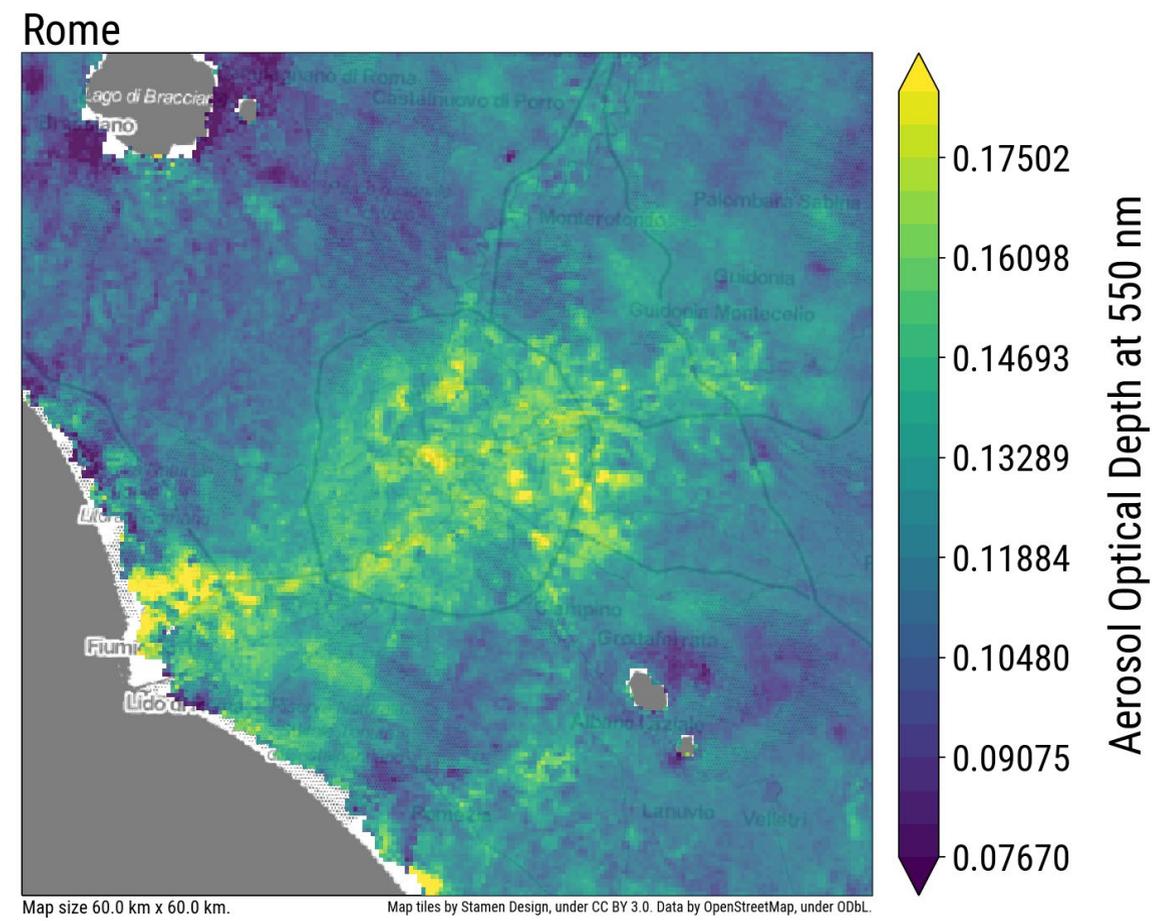
Aerosol Optical Depth at 550 nm

Very high AOD!

# Rome, Italy

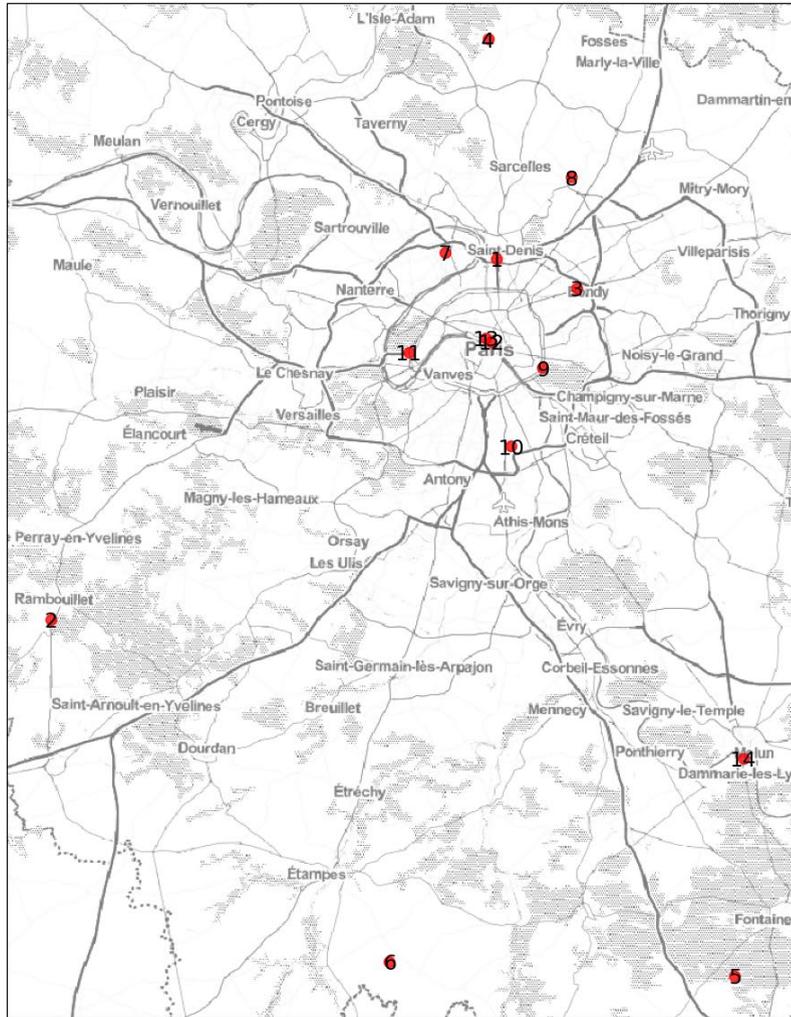
# Average AOD for July 2019

Synergy AOD  
+ post-process  
correction



# Air Quality

# Paris, France

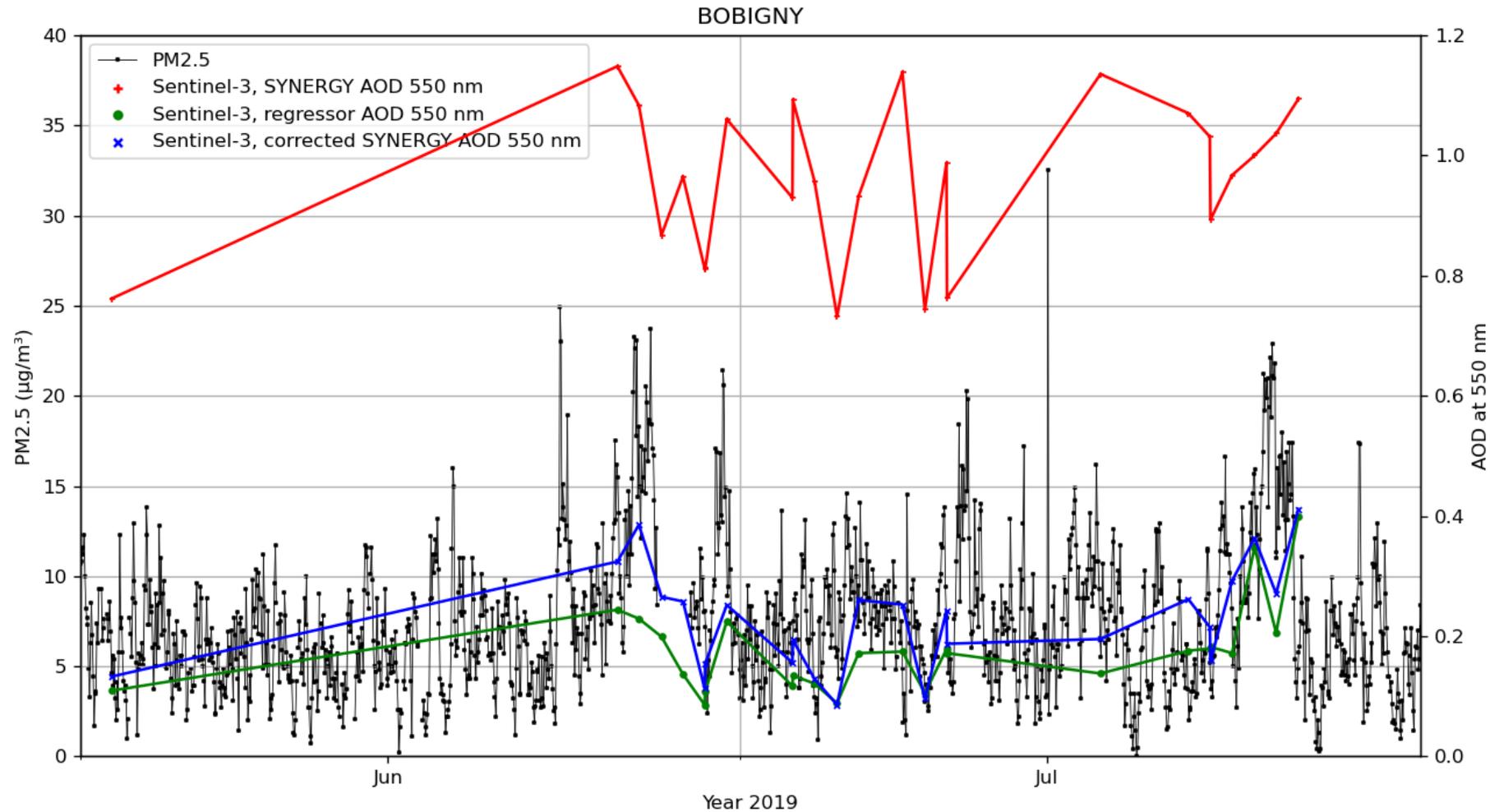


- 1: Autoroute\_A1\_-\_Saint-Denis
- 2: Rambouillet
- 3: BOBIGNY
- 4: Zone\_rurale\_Nord\_-\_Saint-Martin-du-Tertre
- 5: Zone\_rurale\_Sud-Est\_-\_Forêt\_de\_Fontainebleau
- 6: Zone\_Rurale\_Sud\_-\_Bois\_Herpin
- 7: GENNEVILLIERS
- 8: GONESSE
- 9: Boulevard\_Périphérique\_Est
- 10: VITRY-SUR-SEINE
- 11: Boulevard\_Péripherique\_Auteuil
- 12: Paris\_Centre
- 13: PARIS\_1er\_Les\_Halles
- 14: Route\_Nationale\_6\_-\_MELUN

Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

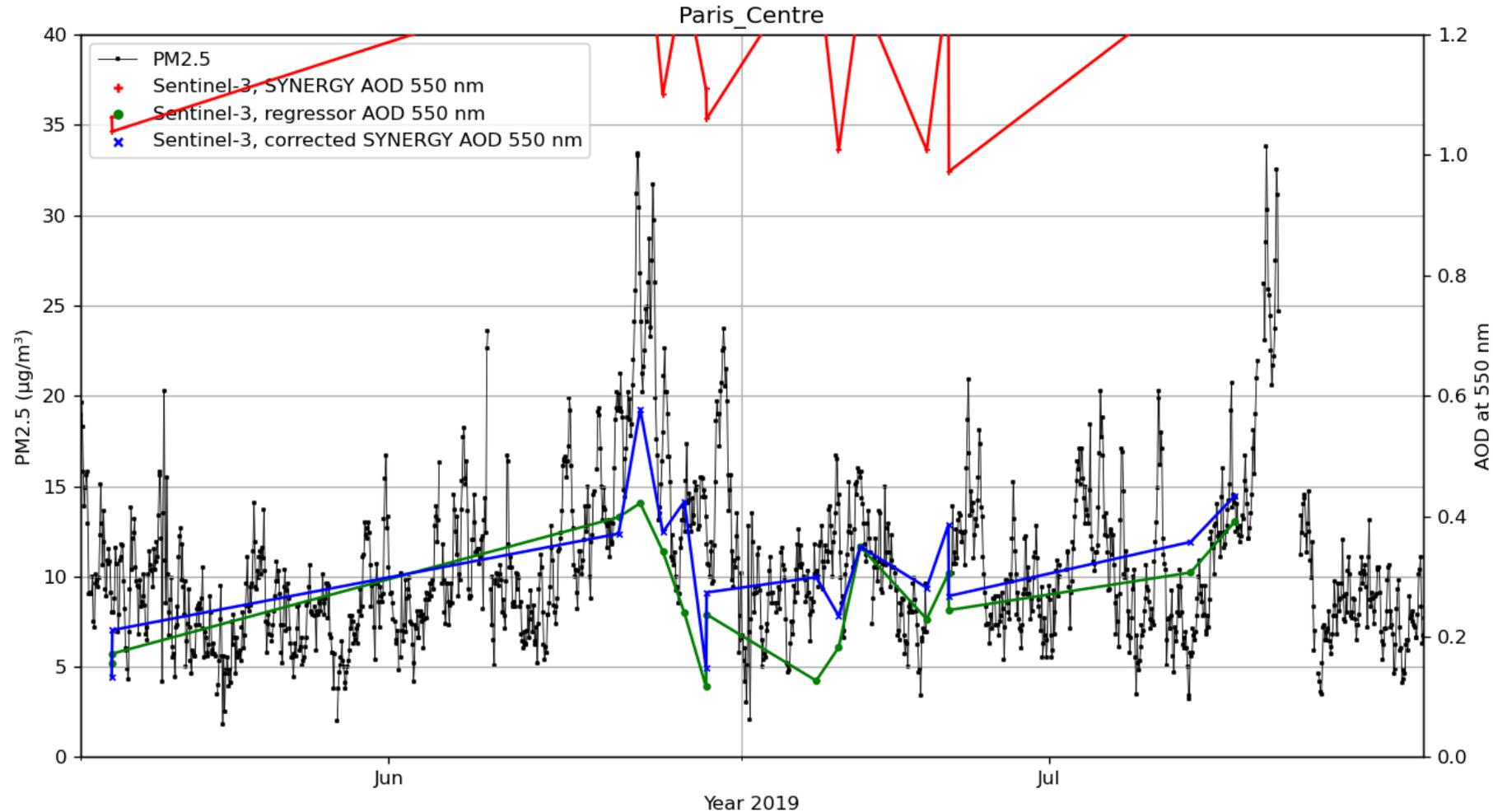
# Air Quality – BOBIGNY, Paris, France

Air quality open data: Airparif <https://www.airparif.asso.fr>



# Air Quality – Paris\_Centre, Paris, France

Air quality open data: Airparif <https://www.airparif.asso.fr>



## Summary, conclusions and future applications

Paper submitted: A. Lipponen et al., "Deep Learning Based Post-Process Correction of the Aerosol Parameters in the High-Resolution Sentinel-3 Level-2 Synergy Product", Atmospheric Measurement Techniques Discussions <https://doi.org/10.5194/amt-2021-262>

Data openly available: [https://a3s.fi/swift/v1/AUTH\\_ca5072b7b22e463b85a2739fd6cd5732/POPCORNdata/readme.html](https://a3s.fi/swift/v1/AUTH_ca5072b7b22e463b85a2739fd6cd5732/POPCORNdata/readme.html)

- We have developed a post-processing algorithm to improve the accuracy of satellite data products. **POPCORN approach combines conventional retrieval algorithms and machine learning.**
- **Method is general** and applicable to any satellite data (given suitable training data, either observational or simulated is available)
- **We see great potential in our approach.** We showed that our approach significantly improves the accuracy of the SYN AOD satellite data product
  - Post-process correction is better than the machine learning only approach
- Potential future applications: high-resolution air quality monitoring, surface data products such as solar induced fluorescence (atmospheric correction), greenhouse gas monitoring, etc.