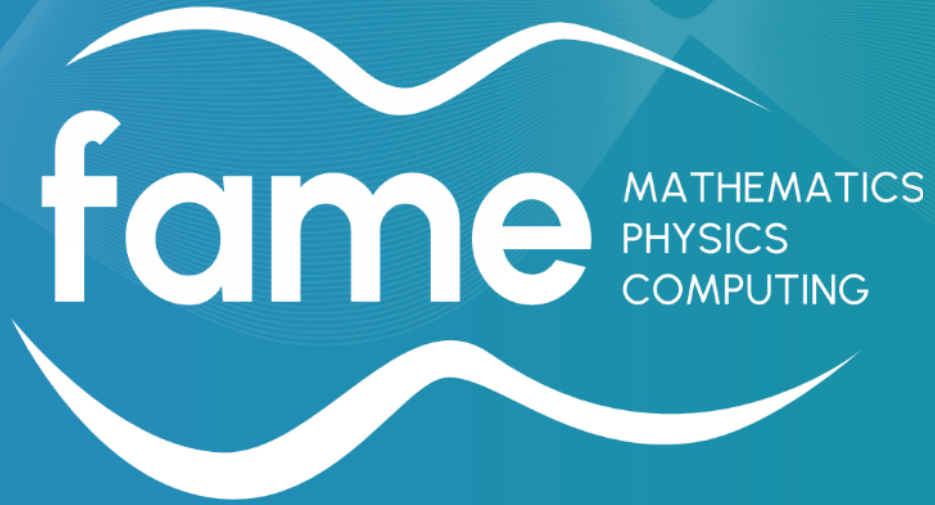


Flagship of Advanced Mathematics for Sensing, Imaging and Modelling (FAME)

Matemaattisen mallinnuksen, havainnoinnin ja kuvantamisen lippulaiva

Prof. Johanna Tamminen, Finnish Meteorological Institute

FAME vision

"Shaping the future with mathematics, physics and computing"

- FAME is an internationally leading competence centre of applied mathematicians, physicists, and applied scientists.
- Based on Center of Excellence on Inverse Modelling and Imaging (2018-2025)
- We provide cutting-edge methods of inverse mathematics, physics and computational sciences
- Aim at tackling challenges in sensing, imaging, and modelling arising from industry and society to boost Finnish economy and global wellbeing

FAME consortium

fameflagship.fi

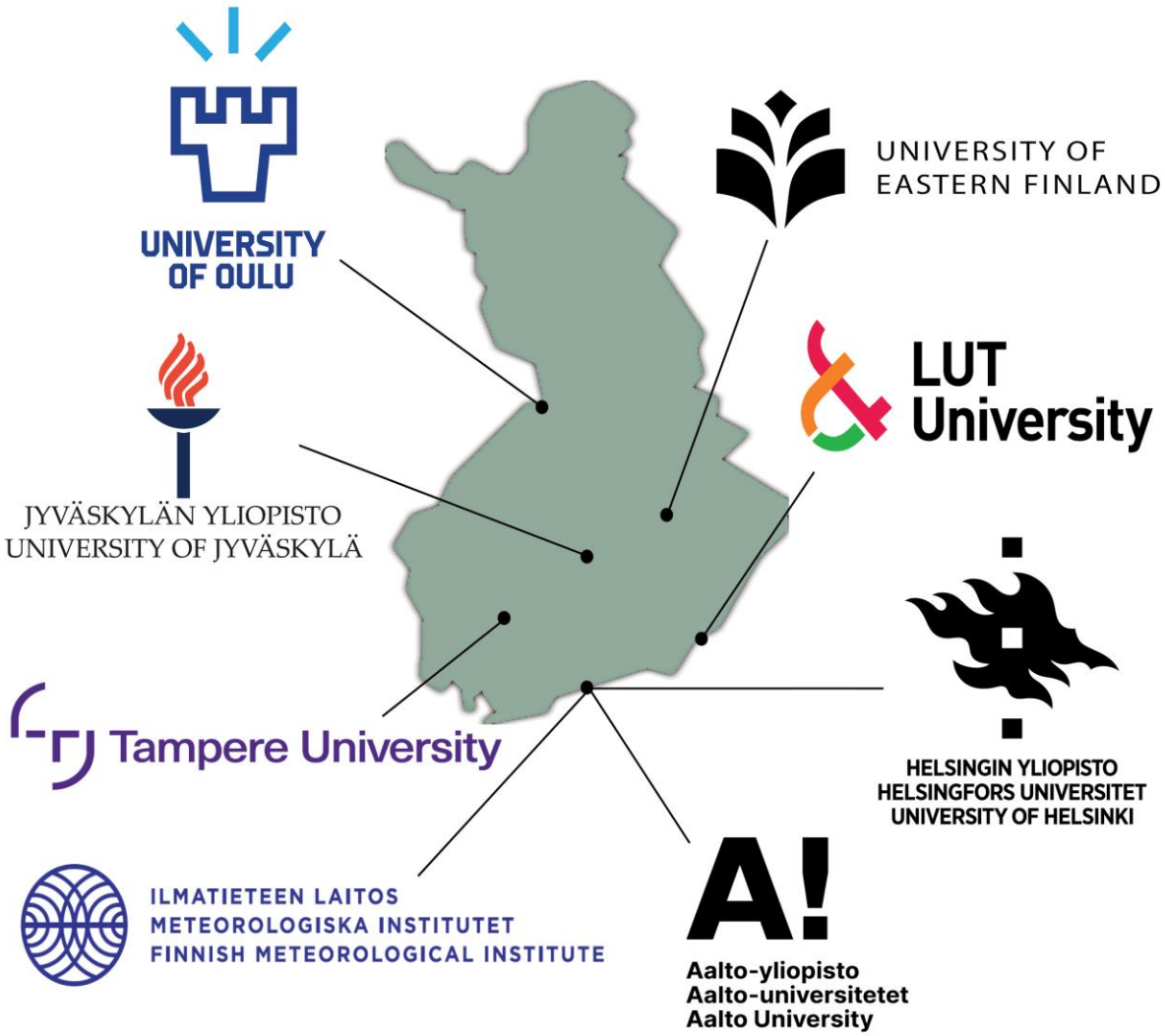
Director: Tanja Tarvainen (UEF) Vice-directors: Nuutti Hyvönen (Aalto), Samuli Siltanen (UH)

Academic partners

- Mathematicians, physicists, medical doctors, biochemists, …
- 8 partners
- 43 principal investigators
- 276 researchers
- 2 coordinators

Stakeholders

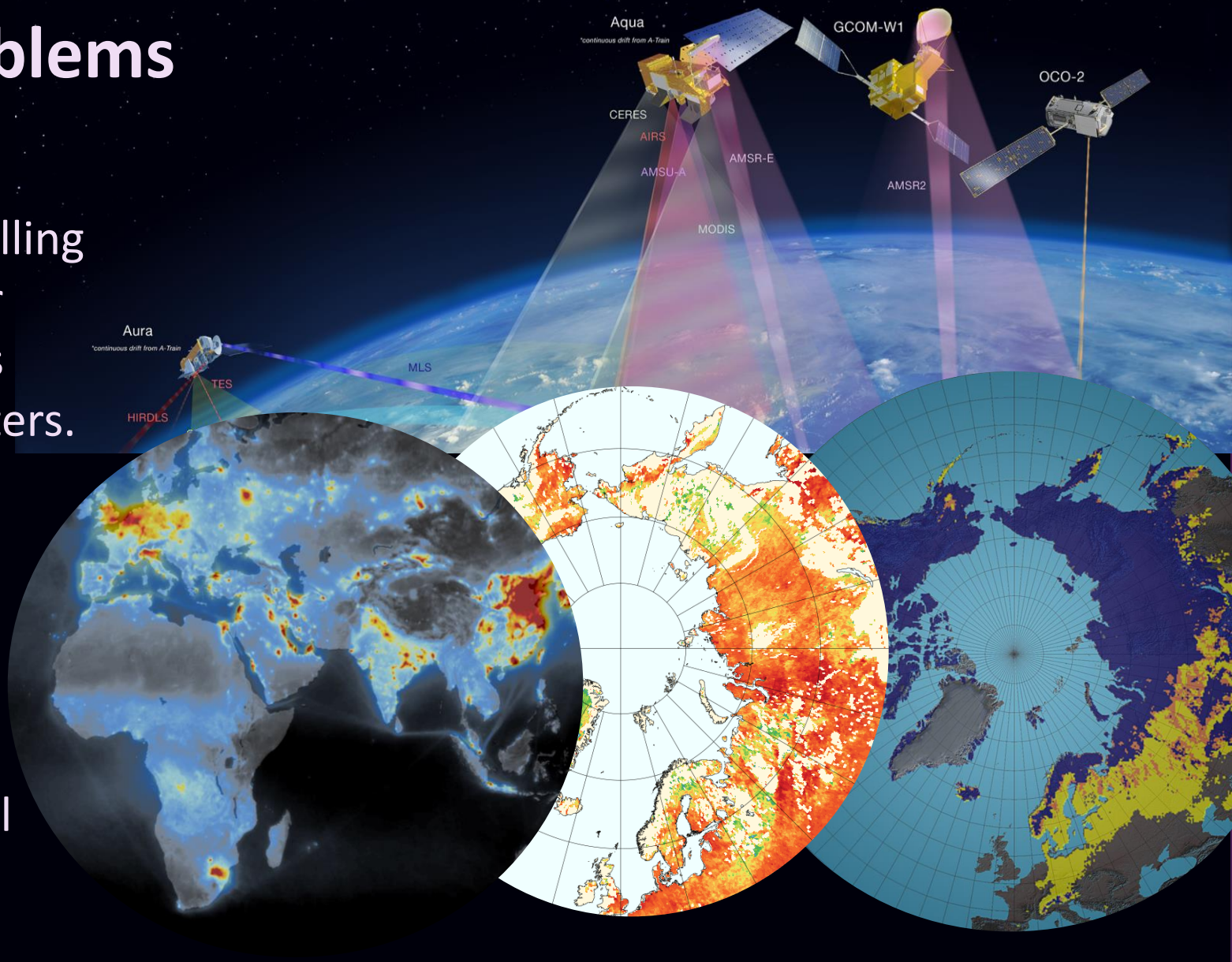
- Companies, university hospitals, organisations, schools, etc. 34 collaborators gave their support letters for the application.
- New stakeholders welcome



Organisation of the FAME Flagship

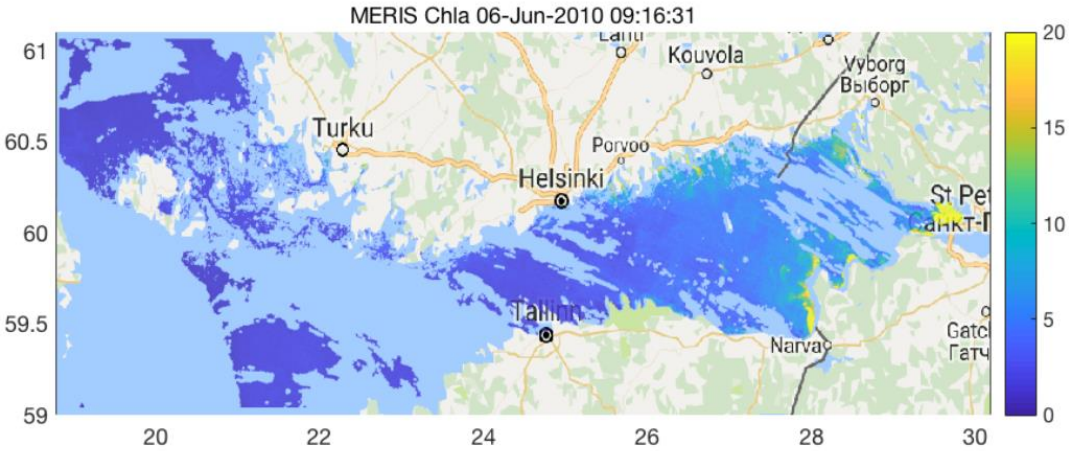
Satellite remote sensing involves solving an inverse problems

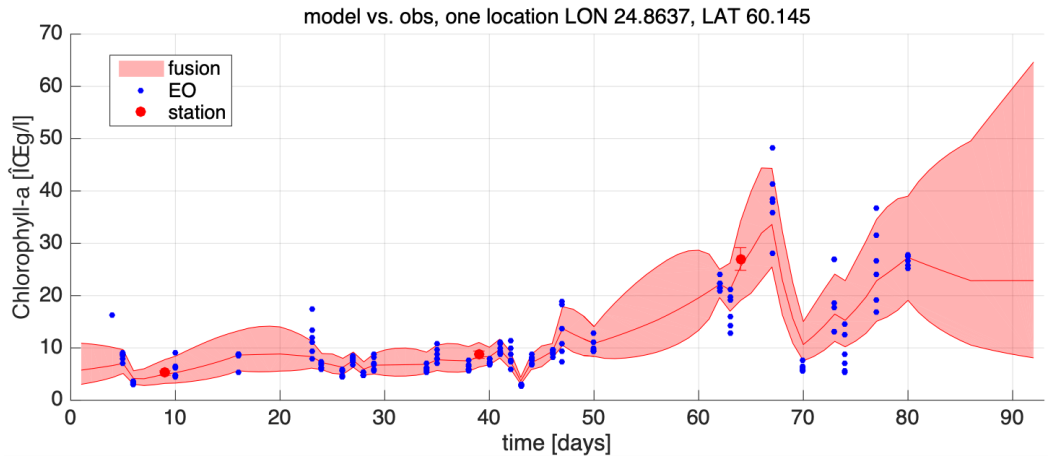
- Forward modelling, inverse modelling and uncertainty quantification for interpreting satellite observations and deriving geophysical parameters.
  - Bayesian methods, AI, time series, data fusion, MCMC, …
- Atmospheric composition, air pollution, greenhouse gases, SIF, land surface parameters, cryosphere parameters (snow, soil state)



Chlorophyll-a: high dimensional spatio-temporal data fusion

- Bayesian hierarchical modelling for high dimensional filtering and smoothing.
- Physics based deep learning for the process model.
- Applications: combining satellite and in-situ data, short term weather forecasting.
- In collaboration with NASA/JPL, Aalto and SYKE.



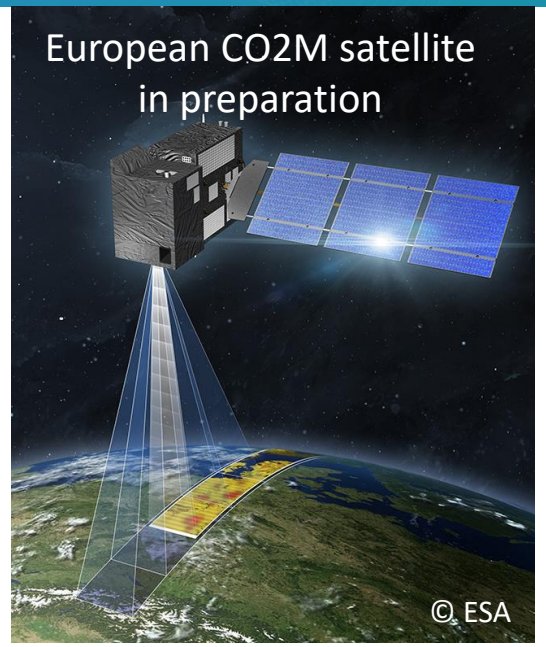


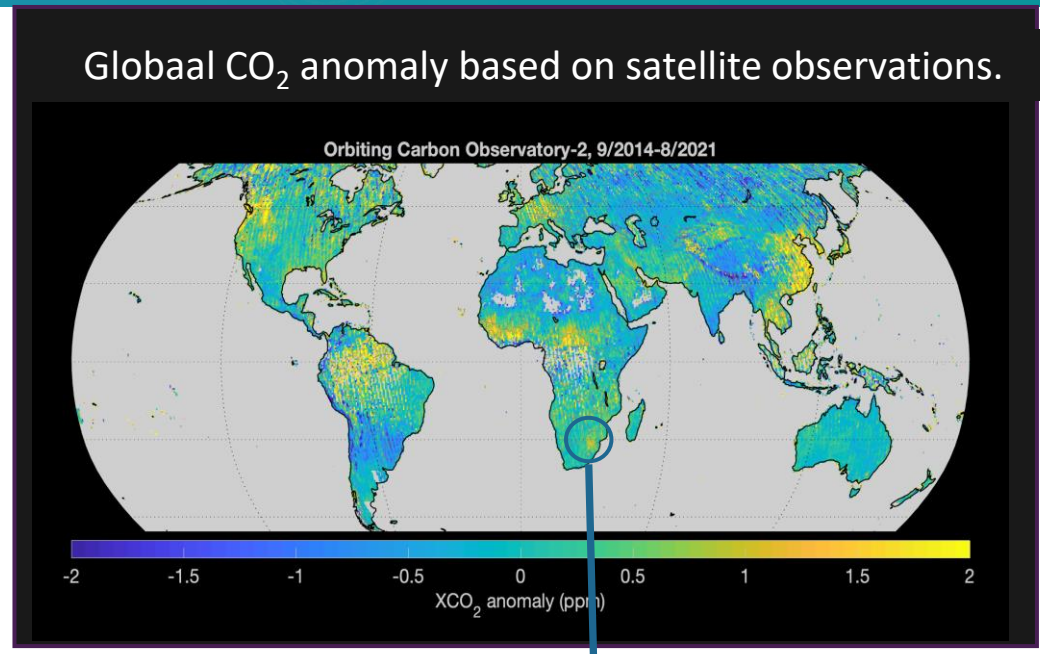
Laine [FMI]

Greenhouse gases and anthropogenic emissions

Develop methods to analyse satellite observations of greenhouse gases and anthropogenic emisisons.

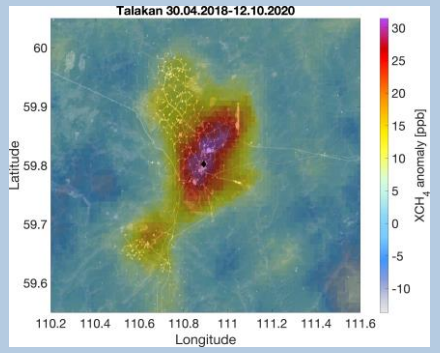
- Baysian techniques
- Uncertainty quantification
- Radiative transfer forward model development
- Dimension reduction
- Characterization of a prior information
- Reference observations
- Supporting new satellites with improved spatial coverage and resolution

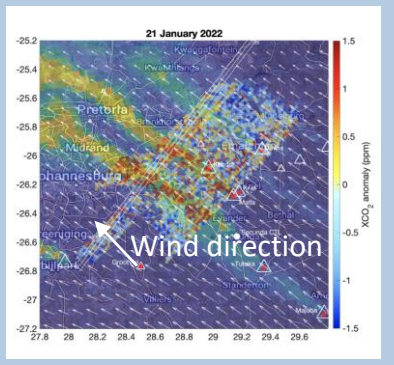




Local GHG emissions as seen by satellites.

Unreported emissions Methane emissions from oil and gas industry in Russia





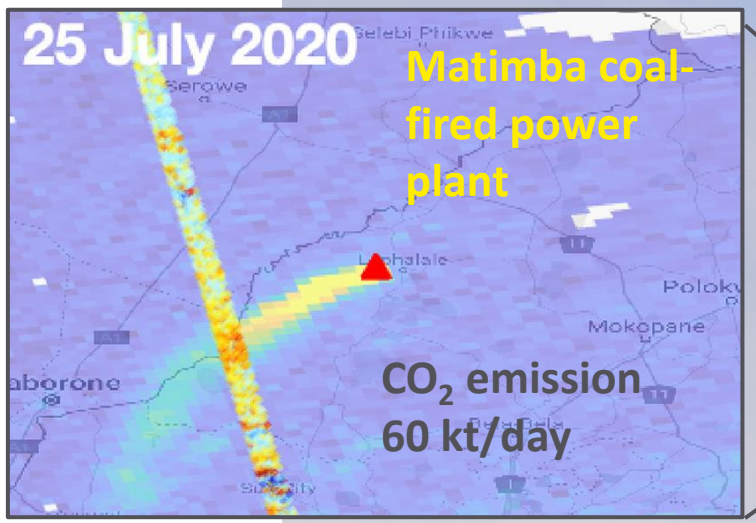
Large CO_2 emission sources in South-Africa..

Tamminen, Lindqvist [FMI]

www.emissionobservatory.org

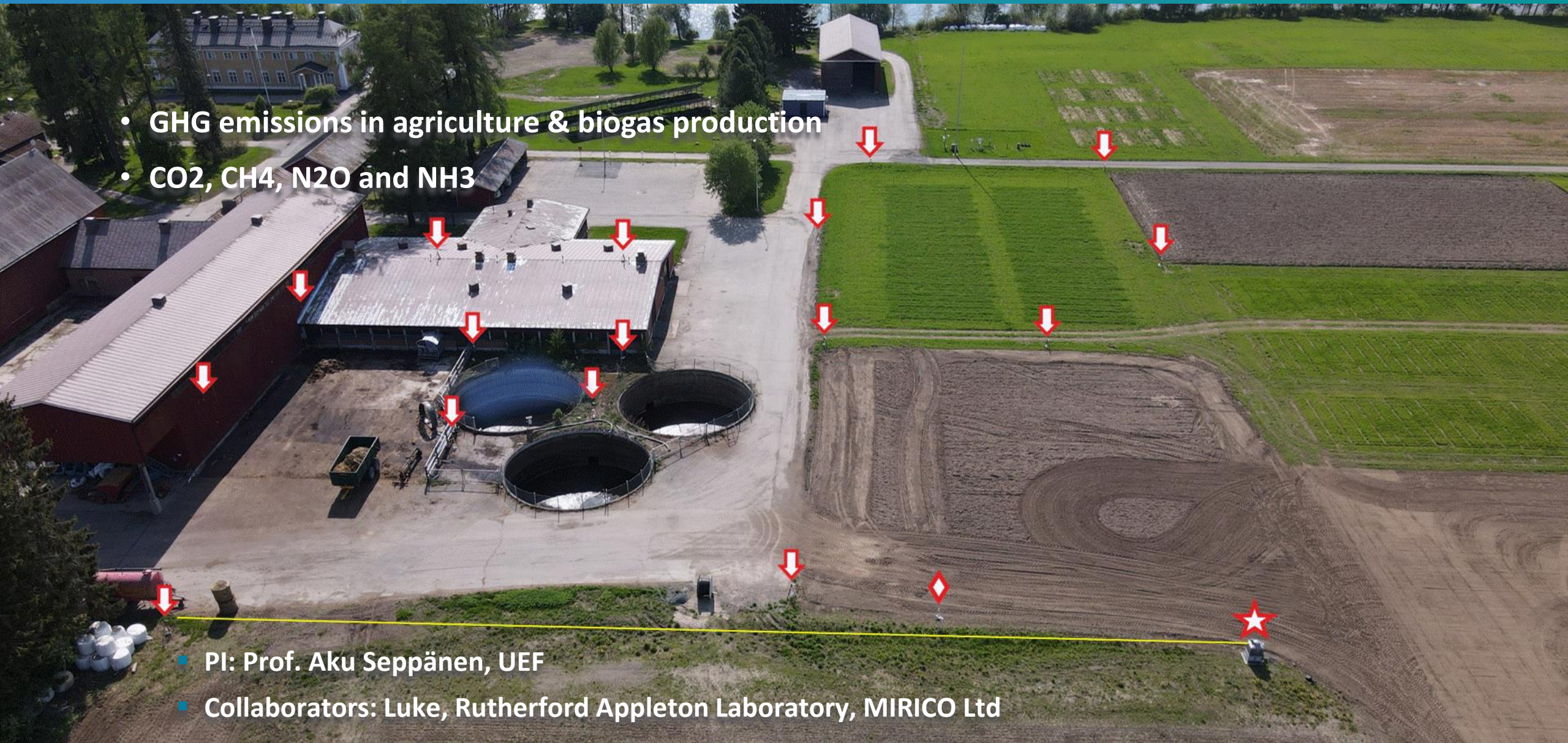
Pilot for Africa

- **Proof-of-Concept study 2024-25 funded by the Research Council of Finland.**
- Development of an online interactive map service for monitoring man-made greenhouse gas and air pollution emission sources.
- The service will provide improved and transparent emission information based on satellite observations (OCO-2/3, Sentinel-5P, supporting CO2M,…)
- Initial focus areas: open pit mining, energy production (e.g., coal-burning power plants) and oil and gas industry (e.g., fugitive methane emissions and gas flaring).
- Target users and stakeholders: decision makers, environmental authorities (Met institutes in Africa), citizens and industry (SSAB, Kuva Space, Rovjok)



Tamminen [FMI]

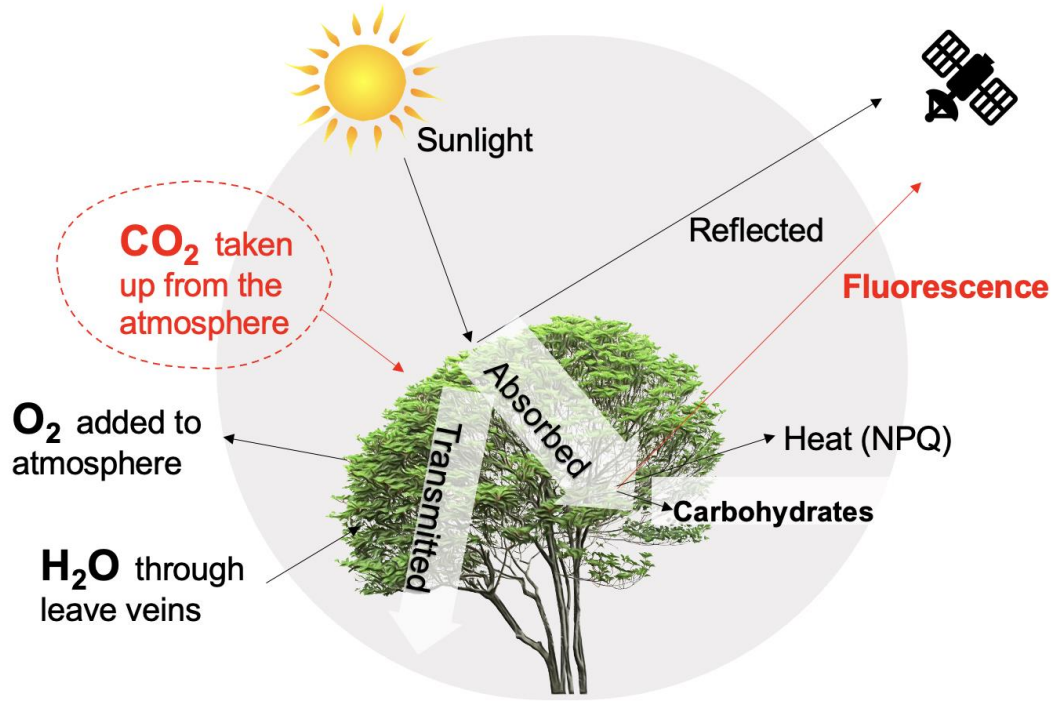
Monitoring of greenhouse gas emissions using laser dispersion tomography



- GHG emissions in agriculture & biogas production
- CO2, CH4, N2O and NH3

- PI: Prof. Aku Seppänen, UEF
- Collaborators: Luke, Rutherford Appleton Laboratory, MIRICO Ltd

Method development for satellite retrieval of solar induced fluorescence (SIF)



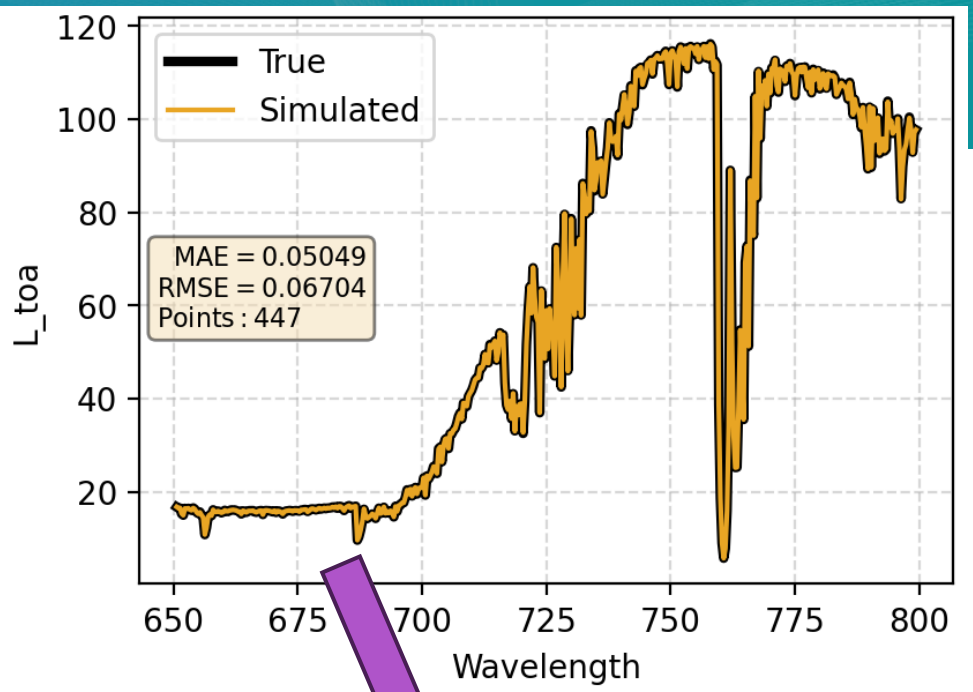
PHOTOSYNTHESIS

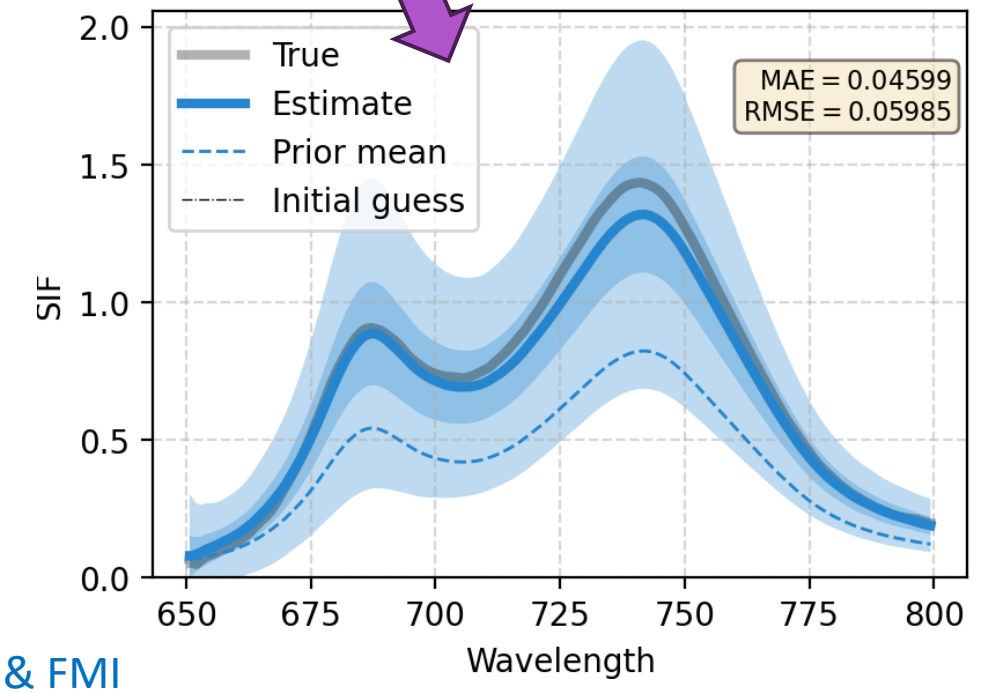
SIFFI: Bayesian non-parametric spectral solar-induced fluorescence retrieval algorithm for remote sensing of vegetation

Antti Kukkurainen[a,b,*], Antti Lipponen[a], Ville Kolehmainen[b], Antti Arola[a], Sergio Cogliati[c], Neus Sabater[a]

[a]*Finnish Meteorological Institute, Kuopio, Finland.*
[b]*University of Eastern Finland, Kuopio, Finland.*
[c]*University of Milano-Bicocca, Milan, Italy.*

In review. *Remote Sensing of Environment.*

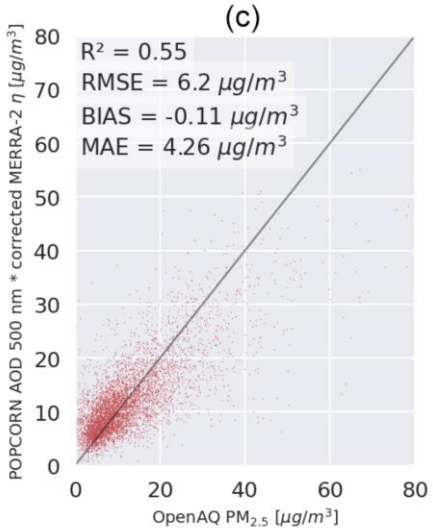


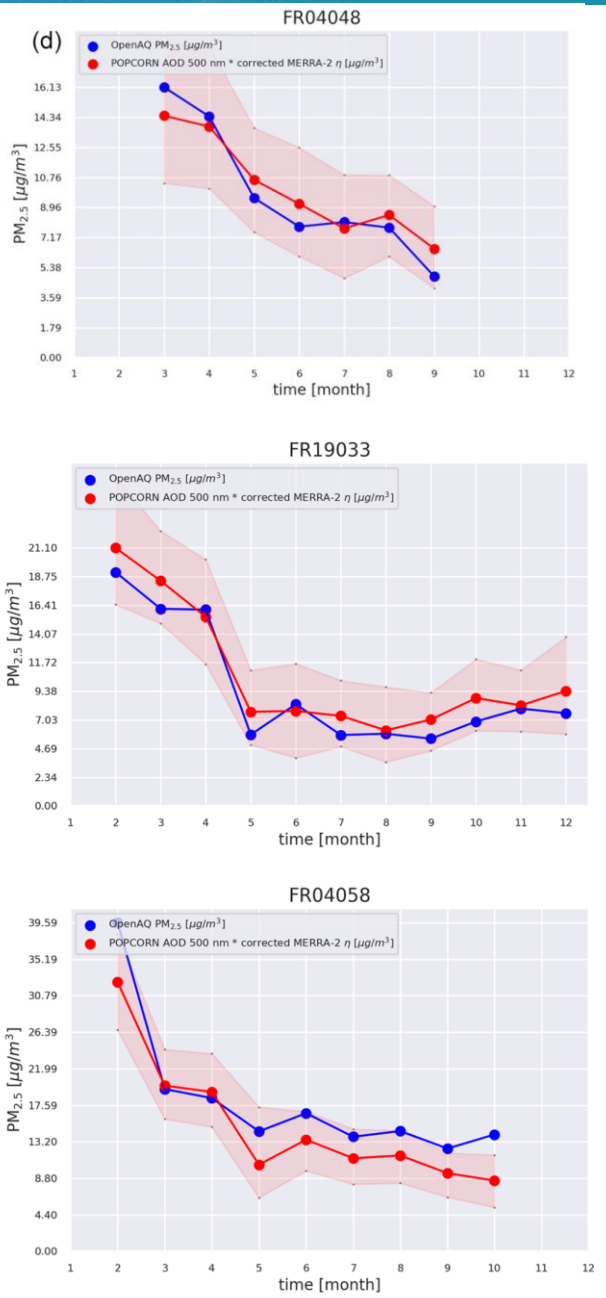


Machine-learning-based data fusion for high resolution spatio-temporal air quality $PM_{2.5}$ estimates

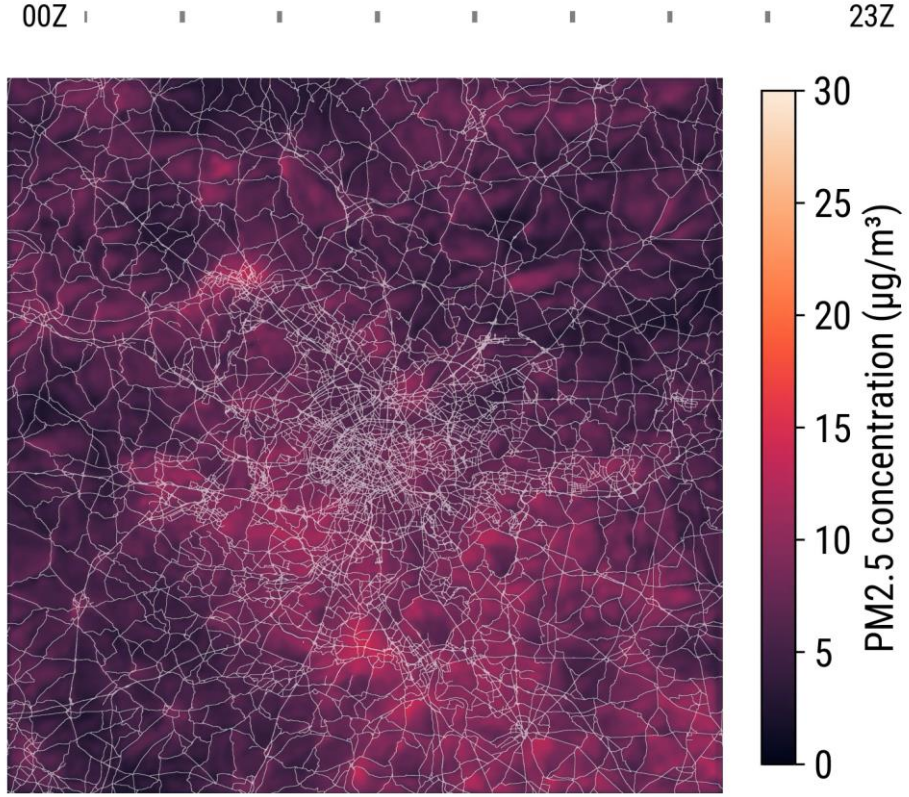
Development of <u>computationally efficient</u> data fusion methods for $PM_{2.5}$ estimation.

Inputs: Satellite AOD + in-situ AQ + model meteorology + aerosols
Output: high resolution spatio-temporal $PM_{2.5}$ estimates (e.g. 1h, 100 meters)





Paris, France 10 January 2019



Post-process correction improves the accuracy of satellite $PM_{2.5}$ retrievals

Andrea Porcheddu[1], Ville Kolehmainen[1], Timo Lähivaara[1], and Antti Lipponen[2]
[1]Department of Technical Physics, University of Eastern Finland, Kuopio, Finland
[2]Atmospheric Research Centre of Eastern Finland, Finnish Meteorological Institute, Kuopio, Finland
Correspondence: Andrea Porcheddu (andrea.porcheddu@uef.fi)

Received: 7 November 2023 – Discussion started: 12 January 2024
Revised: 20 June 2024 – Accepted: 15 July 2024 – Published:

Accepted for publication. *Atmosperic Measurement Techniques.*

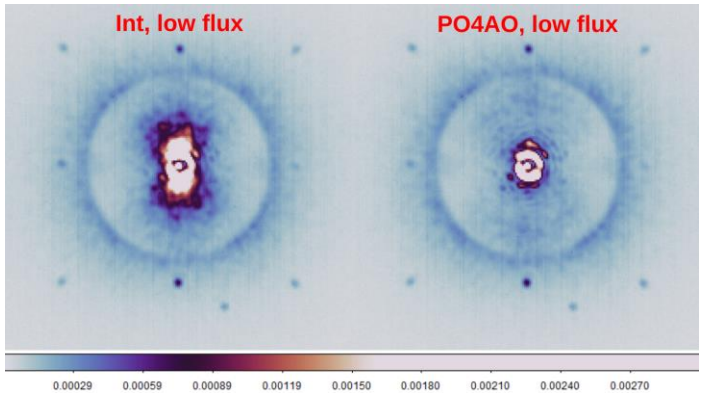
Machine learning data fusion for high spatio-temporal resolution $PM_{2.5}$ prediction

Andrea Porcheddu[1], Ville Kolehmainen[1], Timo Lähivaara[1], and Antti Lipponen[2]
[1]Department of Technical Physics, University of Eastern Finland, Kuopio, Finland
[2]Finnish Meteorological Institute, Atmospheric Research Centre of Eastern Finland, Kuopio, Finland
Correspondence: Andrea Porcheddu (andrea.porcheddu@uef.fi)

Manuscript in preparation

UEF & FMI

Adaptive optics in telescope imaging



Reinforcement learning improves high-contrast imaging in AO (Nousiainen et al. 2022)

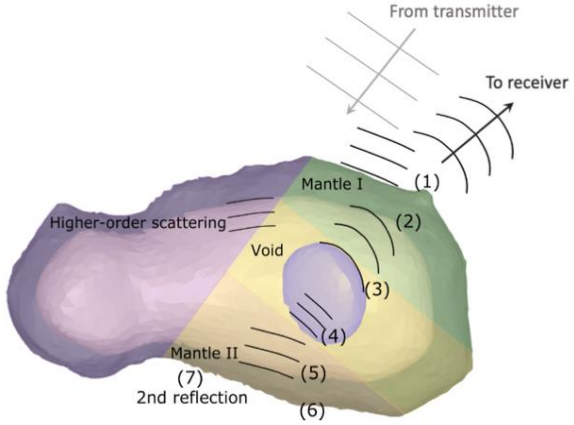
- The Extremely Large Telescope (ELT) commissioned by the European Southern Observatory (ESO) will be the **world's largest** optical/near-infrared telescope at the time of its launch in 2028
- **Inverse problems** are in the core of the algorithmic challenges faced by the next-generation telescope imaging by ELT
- LUT team collaborates with the ESO on developing mathematical methods in **adaptive optics** and has participated the ELT instrumentation project MICADO
- We are frontrunners in developing reinforcement learning in adaptive optics to calibrate the imaging system online

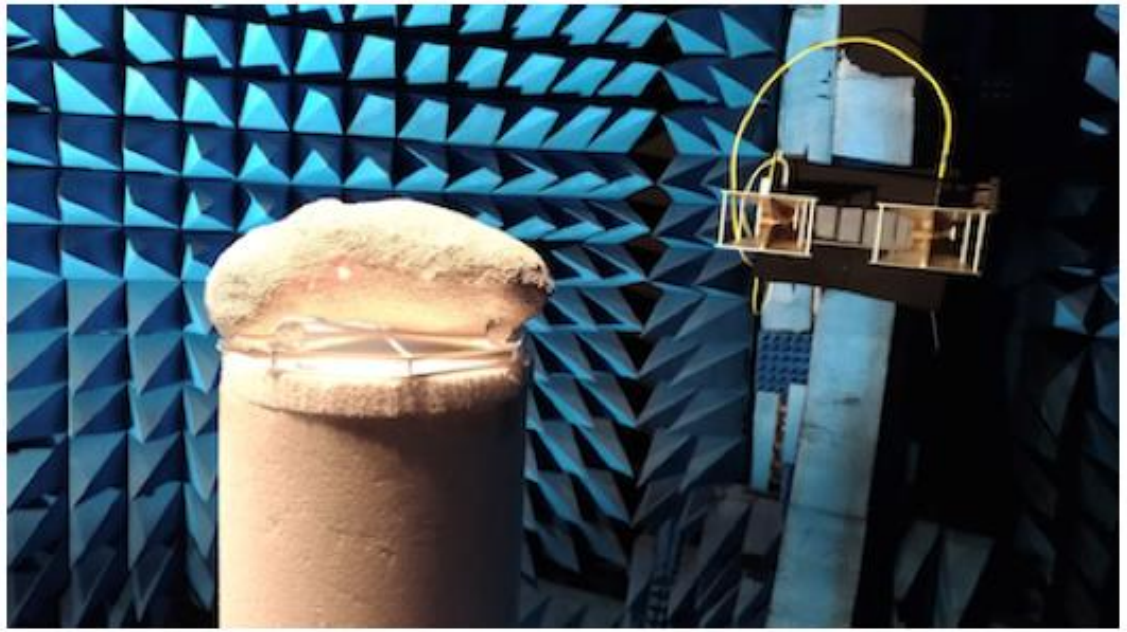
Nousiainen et al. JATIS 2024
Nousiainen, PhD thesis@LUT, 2023
Helin et al. Inverse Problems 2018
Helin et al. Inverse Problems 2013

Helin et al. [LUT]

Tomography in Deep Space – Reconstructing Asteroid Interior

- TAU develops and utilizes 3D-printed asteroid scale models to experimentally validate wave propagation and inversion models in controlled environments, ensuring accuracy before applying them to space mission data.
- The asteroid tomography in the right diameter-to-wavelength ratio (corresponding to 160 m diameter and 60 MHz signal frequency in JuRa) poses a significant computational challenge which at TAU is tackled by leveraging high-performance computing resources.
- Over the past 8 years, TAU's asteroid tomography research has been supported by multiple projects funded by the Research Council of Finland and Finnish Foundations. This continuous funding has played a crucial role in advancing radar tomography techniques and supporting the international collaboration.



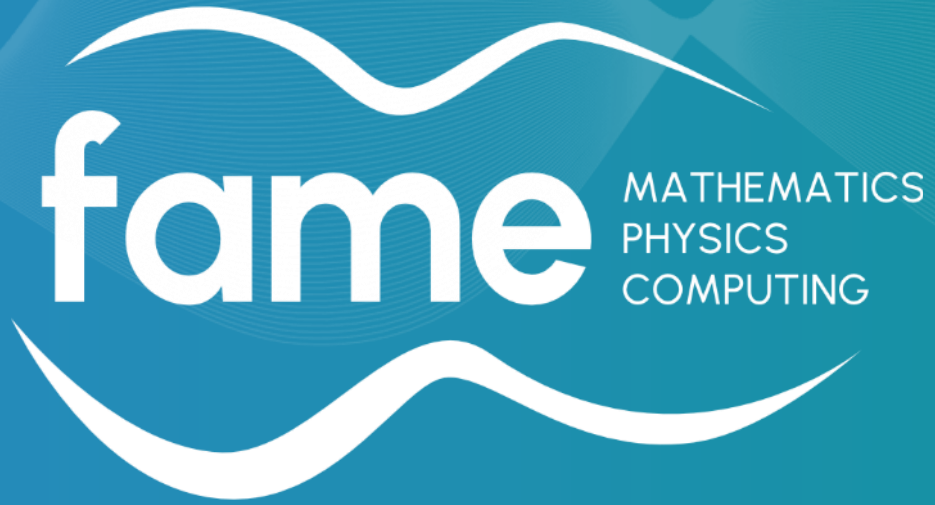


Pursiainen et al [TAU]

Join FAME Flagship Connect & Collaborate networking event to connect with leading scientists in computational solutions!

- FAME arranges the event for companies, organisations, and other stakeholders **10 October in Helsinki**, at the event and conference center Sofia (Sofiankatu 4c), **at 13:00–19:00.**
- The event starts with the presentations of FAME Flagship's researchers who are introducing FAME expertise and opportunities for companies and societal impact
- Two representatives from each organisation are warmly welcome!
- **Register here**: https://link.webropolsurveys.com/EP/BD947414BBA6561A
- More information: FAMEcoordinator@uef.fi

fame MATHEMATICS PHYSICS COMPUTING



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