Exploiting Optical Particle Counters measurements and satellite retrievals to infer local aerosol properties over urban areas

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Well-documented **health effects of aerosol** pollution, especially in urban areas

Insufficient monitoring of Particulate Matter (**PM**) mass concentration

Satellites data can extend the monitoring in regions with sparse ground-based networks

Methodologies to use satellite Aerosol Optical Depth (**AOD**) to create PM maps

Optical Particle Counter (OPC) data offer information about aerosol Particle Size Distribution (PSD) and other properties

Examples of studies applied to Italy

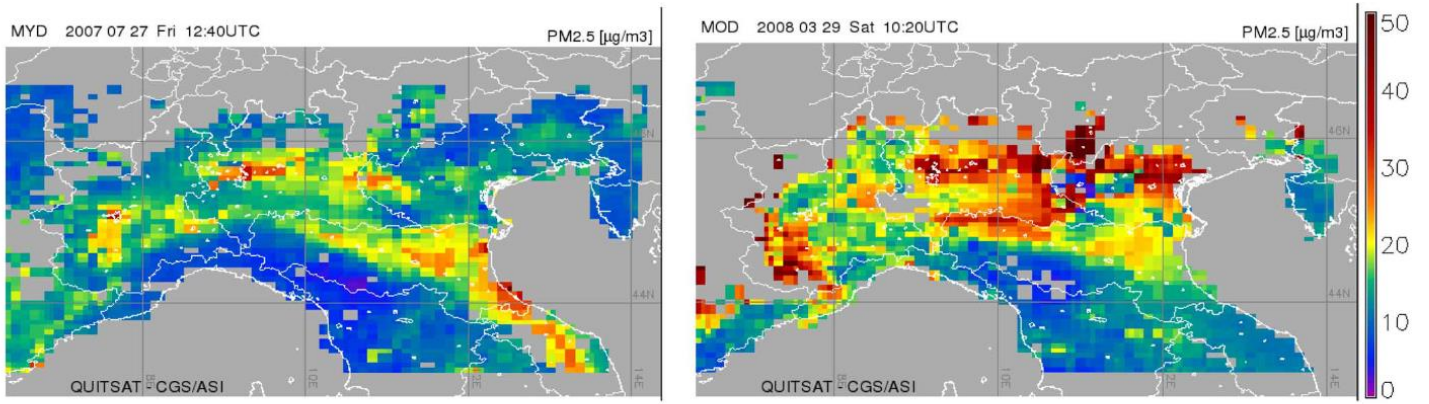
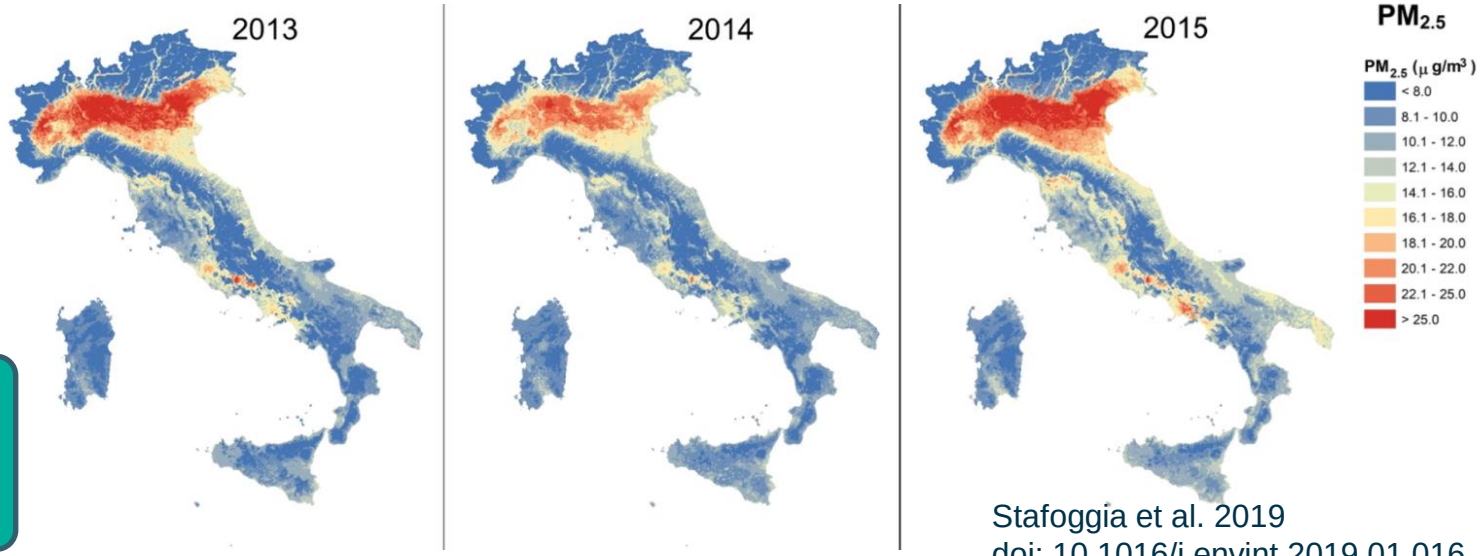


Fig. 3. MODIS/Aqua-based $PM_{2.5}$ maps relative to July 27, 2007 (left), and March 29, 2008 (right).

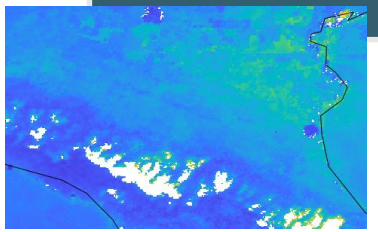
Di Nicolantonio et al. 2009
doi: 10.1109/JSTARS.2009.2033948



Stafoggia et al. 2019
doi: 10.1016/j.envint.2019.01.016

General methodology applied to the study area

AOD maps from satellite retrievals



Knowledge about study area (auxiliary data)

Aerosol properties from OPC data

This study

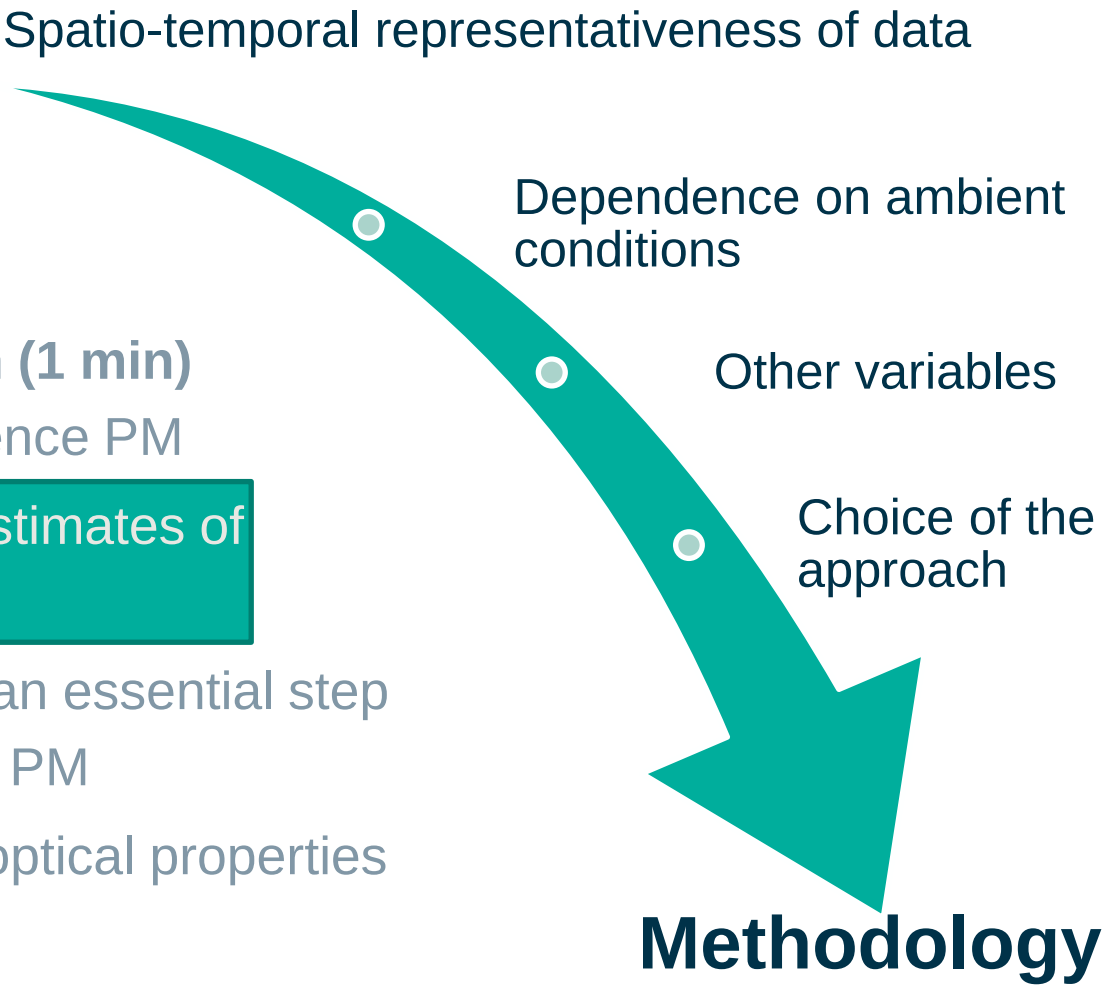
Correction of satellite AOD to estimate PM over the study area using OPC data

Applications (maps of PM over the study area)

Knowledge about local aerosol properties

Correction of satellite AOD

- MAIAC AOD: retrieved from MODIS data at **high spatial resolution** (1 km x 1 km)
- OPC measurements have **high temporal resolution (1 min)** and hourly averages correlate better than daily reference PM
- Ambient conditions (Relative Humidity) affect OPC estimates of PM concentration and AOD retrievals
- Considering the height of the aerosol mixing layer is an essential step in order to correlate columnar AOD with ground-level PM
- We also consider the local aerosol composition and optical properties
- Methodology based on a **physical approach**



Based on Ferrero et al. 2019 and similar studies
doi: 10.1016/j.apr.2019.08.003

Aerosol extinction coefficient at ground level, related to PM

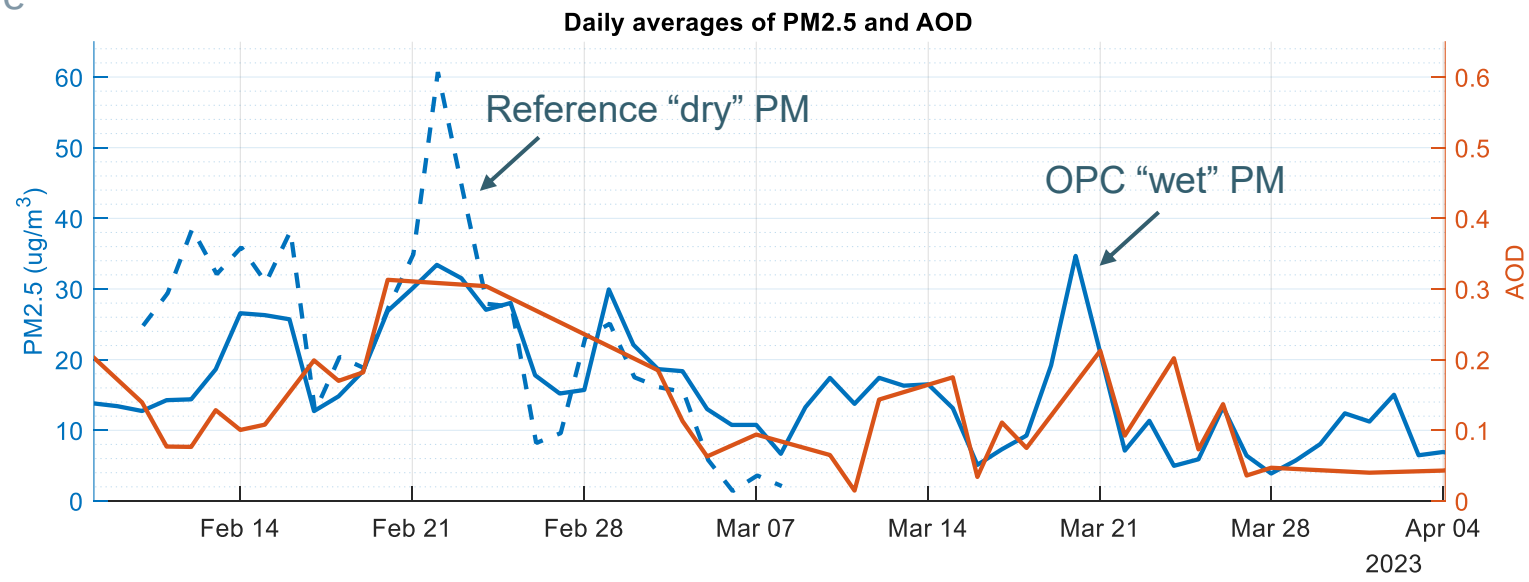
$$\beta_{ext,0} = PM\frac{3}{4}\frac{\langle Q_{ext,aer,wet}\rangle}{\rho_{aer} r_{eff}}$$ → exact formula

Approximation for well-mixed fine aerosols: $AOD \cong \beta_{ext,0}\, PBLH$ and considering $PM_{2.5}$

$$PM_{2.5,wet} \cong \frac{AOD}{PBLH}\frac{4}{3}\frac{\rho_{aer} r_{eff}}{\langle Q_{ext,aer,wet}\rangle}$$

Based on Koelemeijer et al. 2006 and similar studies
doi: 10.1016/j.atmosenv.2006.04.044

- r_{eff} is the Effective Radius of the aerosol Particle Size Distribution (PSD) at ambient conditions
  → from OPC data
- ρ_{aer} is the average aerosol mass density
- $\langle Q_{ext,aer,wet}\rangle$ is the average Extinction Efficiency of the aerosol PSD at ambient conditions
  → $\langle Q_{ext,aer,wet}\rangle = \langle Q_{ext,aer,dry}\rangle C(RH)$
- $PBLH$ is the Planetary Boundary Layer Height
- PM "wet" is affected by ambient conditions

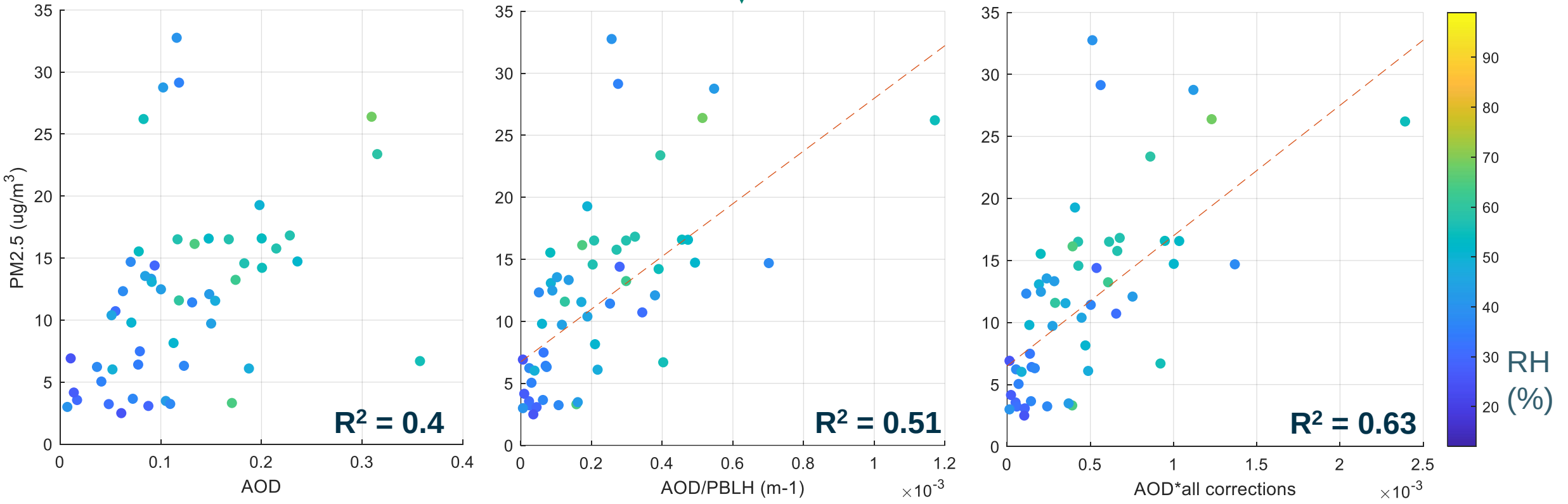


Correction of AOD:

$$PM_{2.5,wet} \cong \frac{AOD}{PBLH} \frac{4}{3} \frac{\rho_{aer} r_{eff}}{\langle Q_{ext,aer,dry} \rangle C(RH)}$$

$$\langle Q_{ext,aer,wet} \rangle = \langle Q_{ext,aer,dry} \rangle C(RH)$$

Data: February-March 2023



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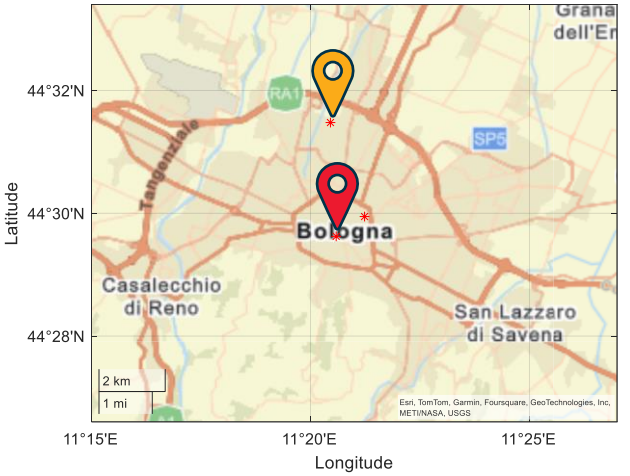
Preliminary results

- Correlation of satellite AOD (corrected with PBLH and OPC-derived properties) and OPC-derived PM
- Possibility of investigating the **RH dependence** of aerosol properties and concentration

Next steps

- Application of the methodology to longer time ranges
- Study of the term $\langle Q_{ext,aer,wet} \rangle = \langle Q_{ext,aer,dry} \rangle C(RH)$ based on aerosol chemical properties and dependence on Relative Humidity
- Use of the methodology within a **physics-informed ML** algorithm → updated daily maps
- Use of other satellite AOD products (eg. From Sentinel-3, Sentinel-5P, …)



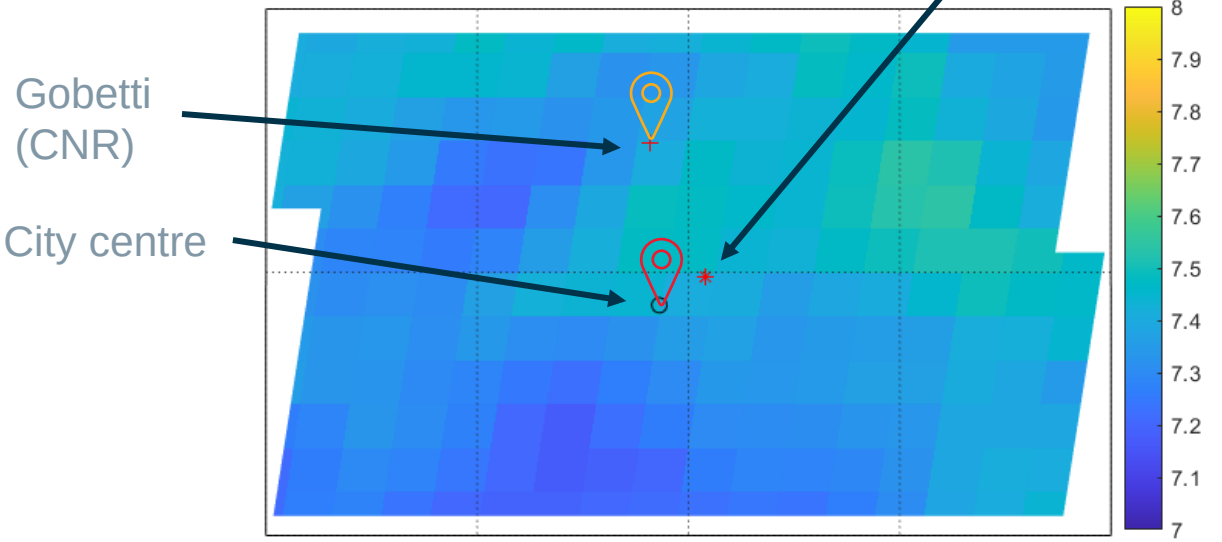
Example of daily PM map over Bologna

Irnerio (measuring site)
Measured PM = 11.13 ug/m3

PM2.5 (ug/m3)

Gobetti (CNR)

City centre



Thank you!

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