Influence of atmospheric dynamics on Paris & London pollution events

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OCAPI, 18 September 2017

Institut Pierre Simon Laplace

SIRTA

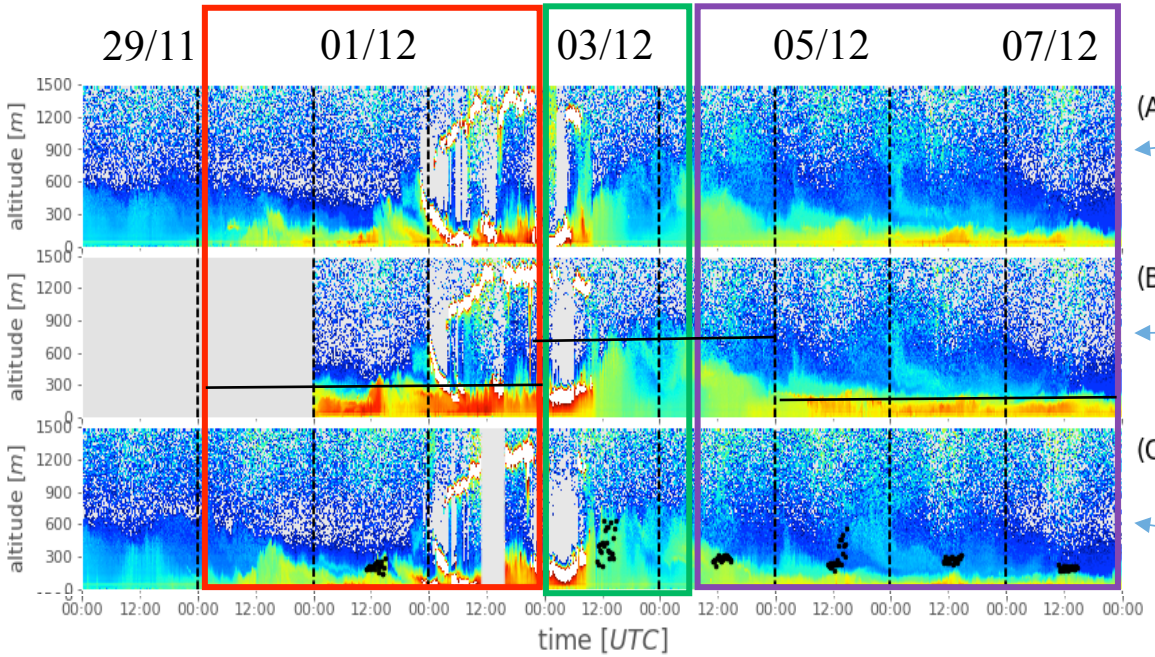
SITE INSTRUMENTAL DE RECHERCHE PAR TÉLÉDÉTECTION ATMOSPHÉRIQUE

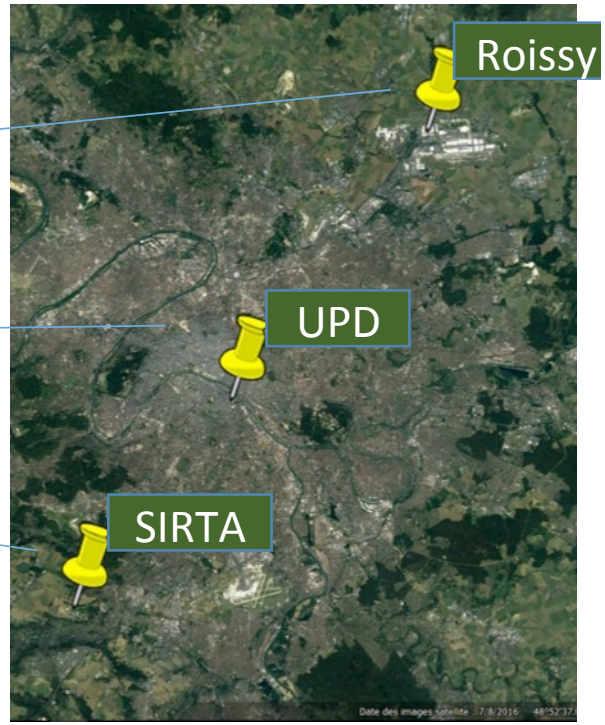
Remote sensing for air-quality assessment?

- Paris megacity suffers several pollution events per year affecting the health of its inhabitants
- Emergency actions to mitigate the pollution effects (for large pollution event)
  - These actions have a large socio-economic impact
- The magnitude of the pollution event is estimated using:
  - PREV'AIR chemistry-transport operational modeling system
  - CHIMERE chemical transport model
- However, there are differences between observations and simulations:
  - Up to 50% in the PM2.5 time series
  - Large uncertainties on NH3 and organic matter concentrations remain
- Differences due to uncertainties in both:
  - chemical processes
  - dynamical and radiative processes

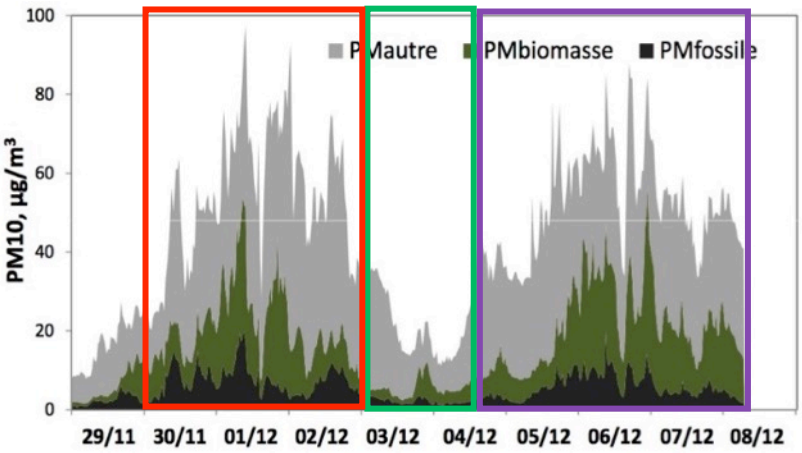
Can we use the remote-sensing measurements to:
- *Improve the knowledge of the dynamical processes?*
- *Contribute to the daily air-pollution forecasts?*

Mixing Layer Height at regional scale



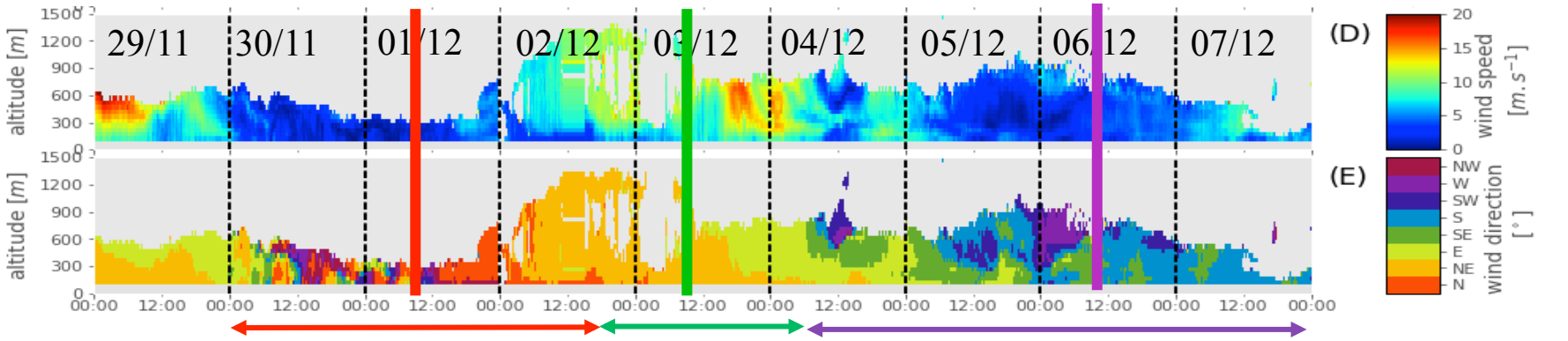


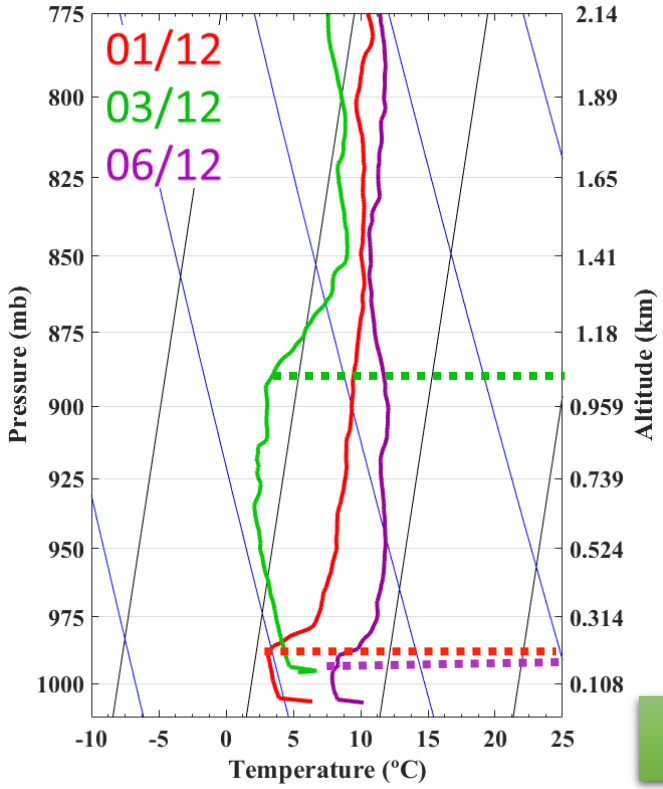
- Ceilometer network → monitor the Mixing Layer Height (MLH) evolution
- Aerosol load distribution is quite consistent at the 3 sites → regional scale of the episode
- Larger MLH in the city center
- 01 and 06/12: MLH≈300 m and PM10≈70 µg/m³
- 03/12: MLH≈900 m and PM10≈20 µg/m³



Behaviour:
↑MLH ⇒ ↓PM10

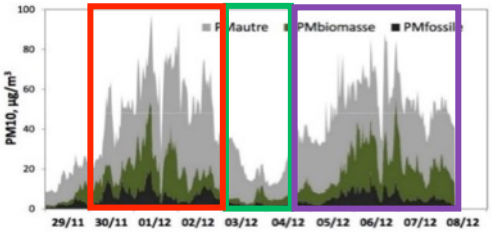
Synoptic situation during the pollution event



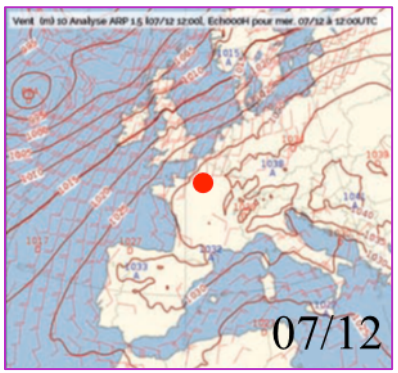


01/12: High pressure center over Paris region → Subsidence inversion

03/12: High pressure moves North → ↑wind speed and ↑MLH



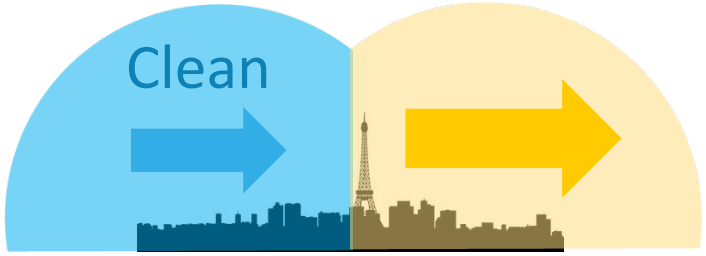
06/12: High pressure over Paris + warm air mass arriving from the South→ thermal inversion



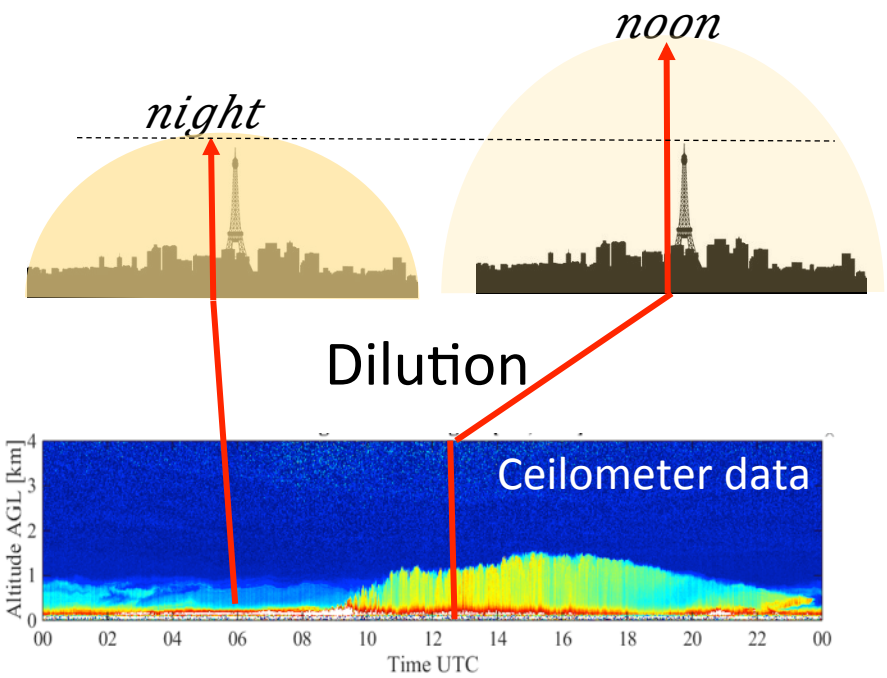
Synoptic situation influences the wind and MLH

Dynamical processes influence PM conc.

Dynamical proceses:



Clean-air advection



Proxy:

wind speed and
wind direction

Mixing layer height

Proxies to classify the pollutant events

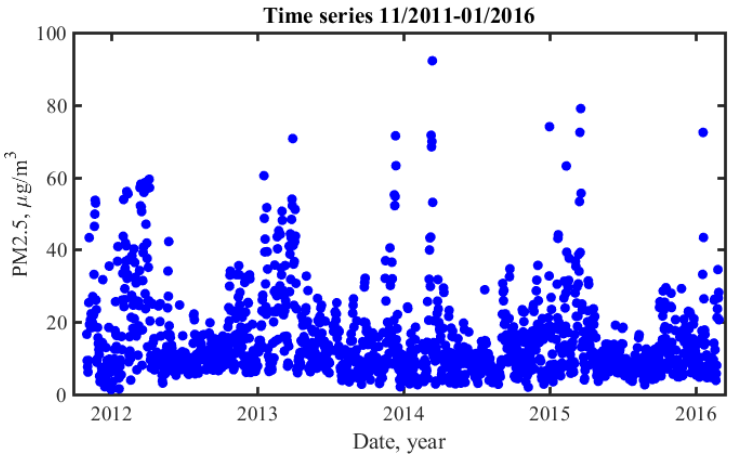
5-year PM2.5: dataset and filters

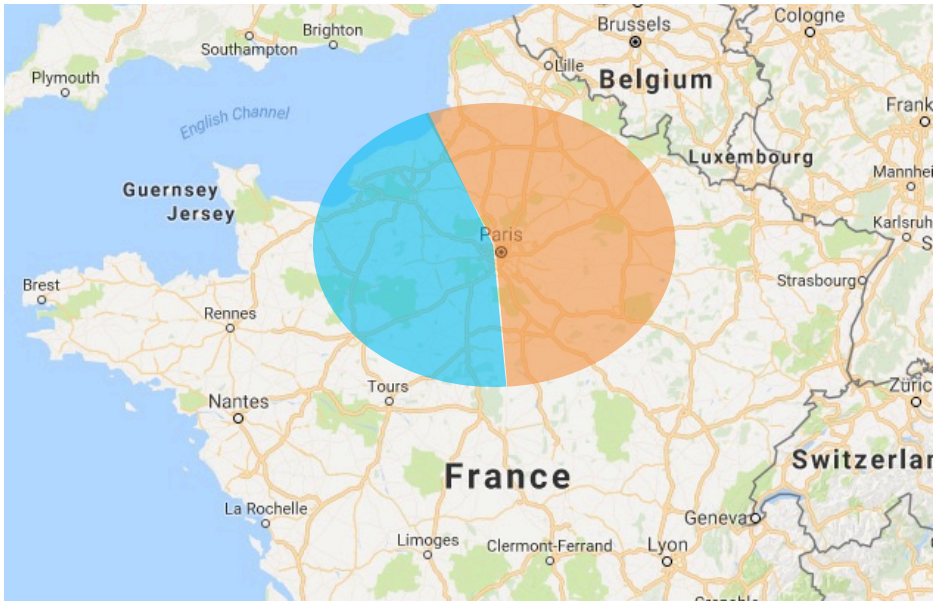
5-year database:

- AIRPARIF daily PM2.5 values on 2011-2015 from VITRY station (20 km from SIRTA)
- Wind speed and direction (SIRTA)
- MLH from radiosondes at noon (SIRTA)

Filtered days:

- Winter
- Non-rainy
- Working (Monday to Friday)
- Continental Vs Oceanic



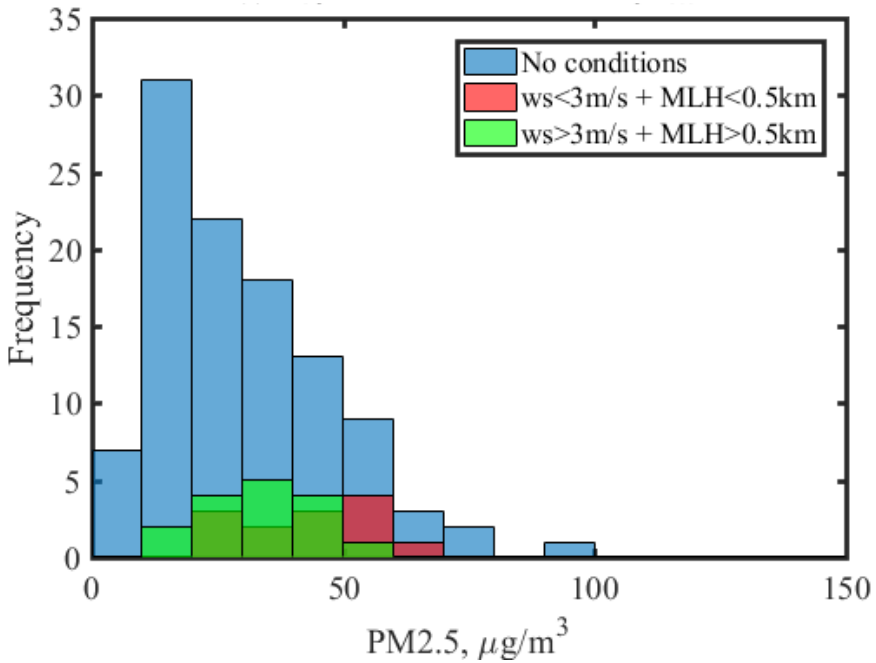


Continental (Northwest-East-South)

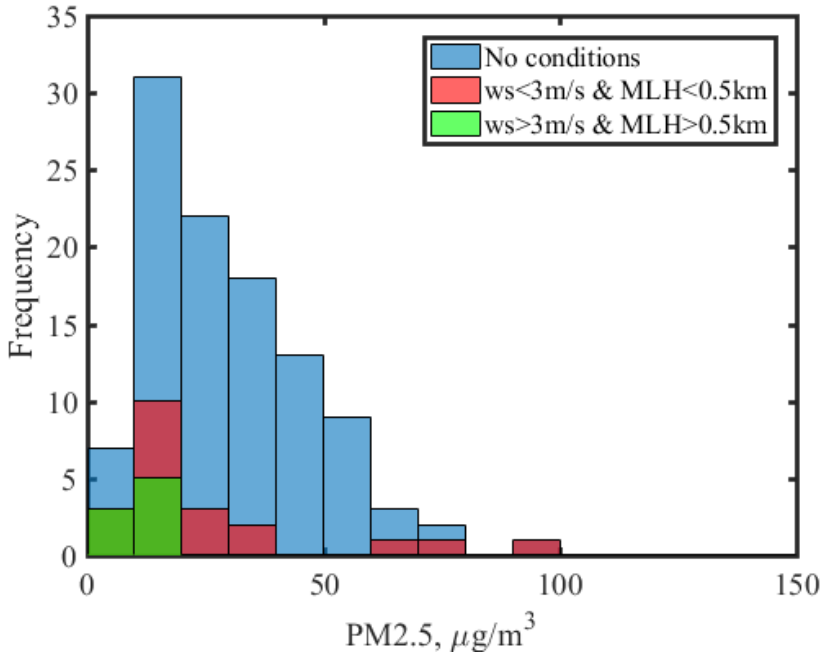
Oceanic (Northwest-West-South)

5-year PM2.5: wind direction influence

Continental



Oceanic



Blue histogram is the same in the two graphs (no conditions)

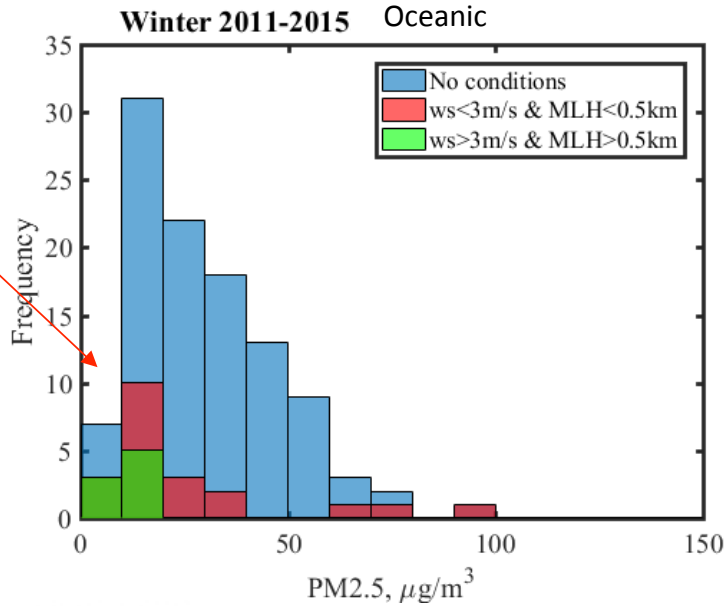
Wind direction:
-Continental → larger PM values (mean ~40 $\mu g/m^3$)
-Oceanic → mainly low PM values + larger impact of wind speed and MLH
-Extreme values (>50 $\mu g/m^3$) always with light wind speed and low ML

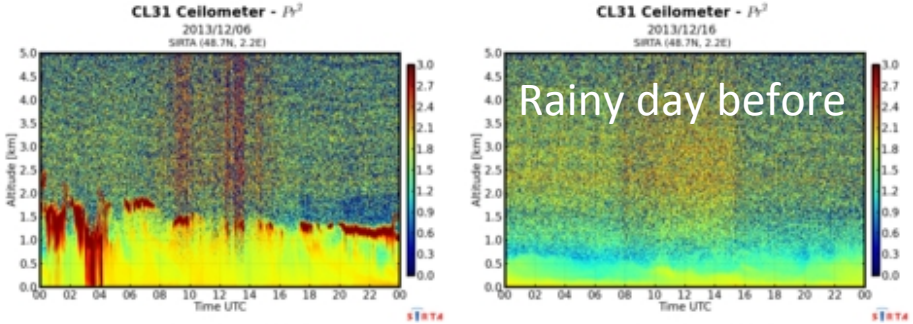
5-year PM2.5: anomalies

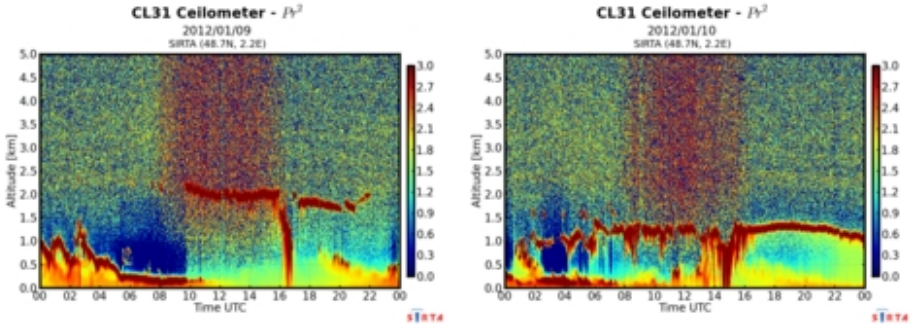
The anomalies:

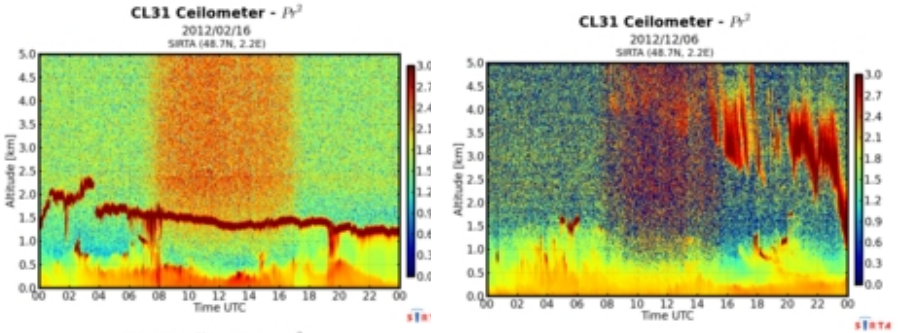
PM<20 $\mu g/m^3$ with light wind speed and low MLH

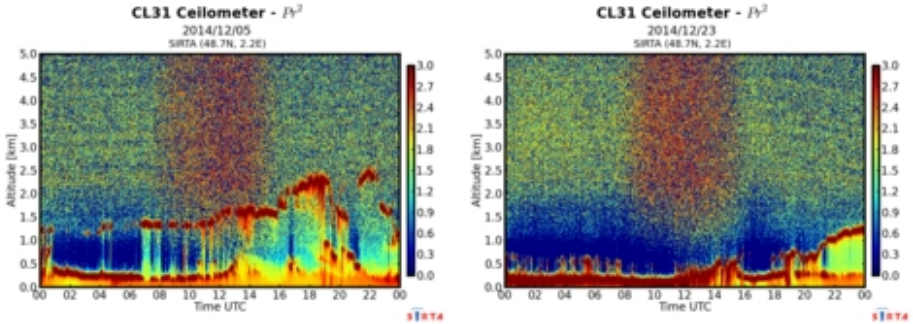
are days with fog or scattered showers

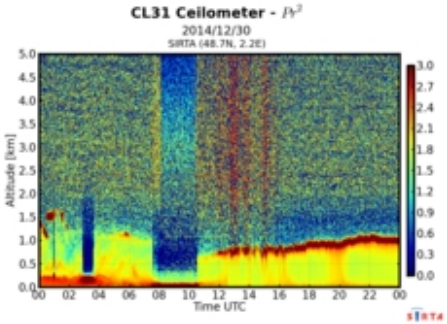






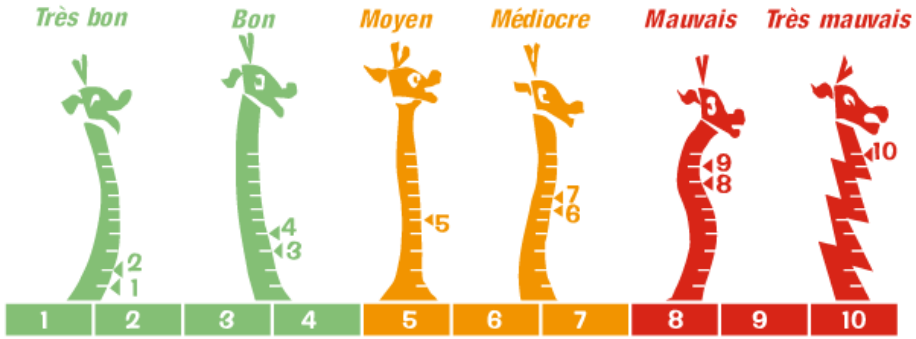






5-year PM2.5 statistical analysis: AIRPARIF index

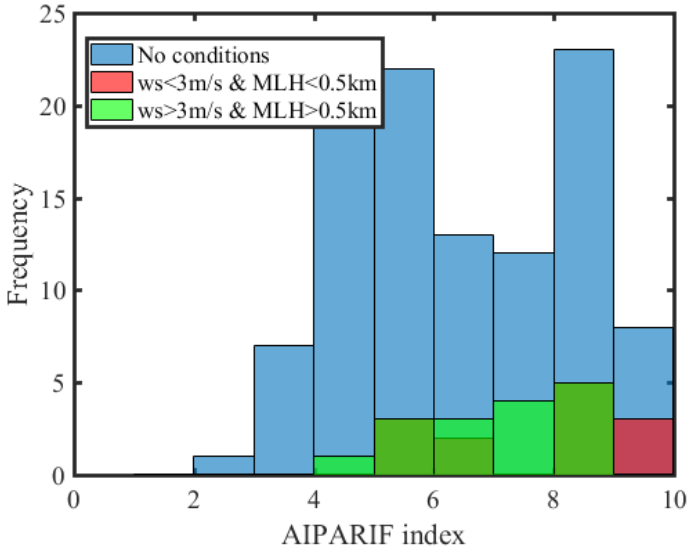
AIRPARIF uses an air-quality index to characterize the pollution events occurred in Paris:
It is based on PM10, O3, SO2 and NOX



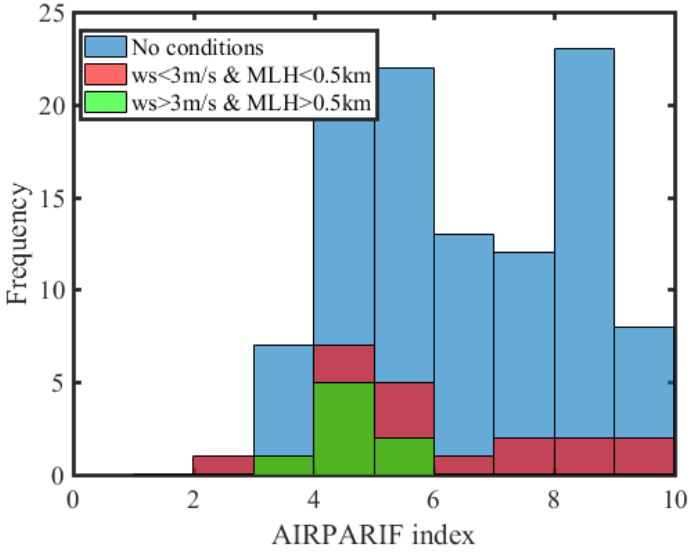
AIRPARIF air-quality index

Using only the PM10 alerts

Continental air mass



Oceanic air mass



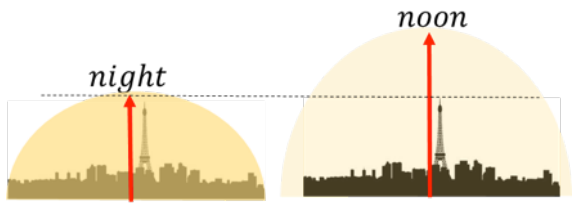
Continental wind direction → AIRPARIF index > 5

Advection of polluted air masses when wind direction is continental

Conclusions

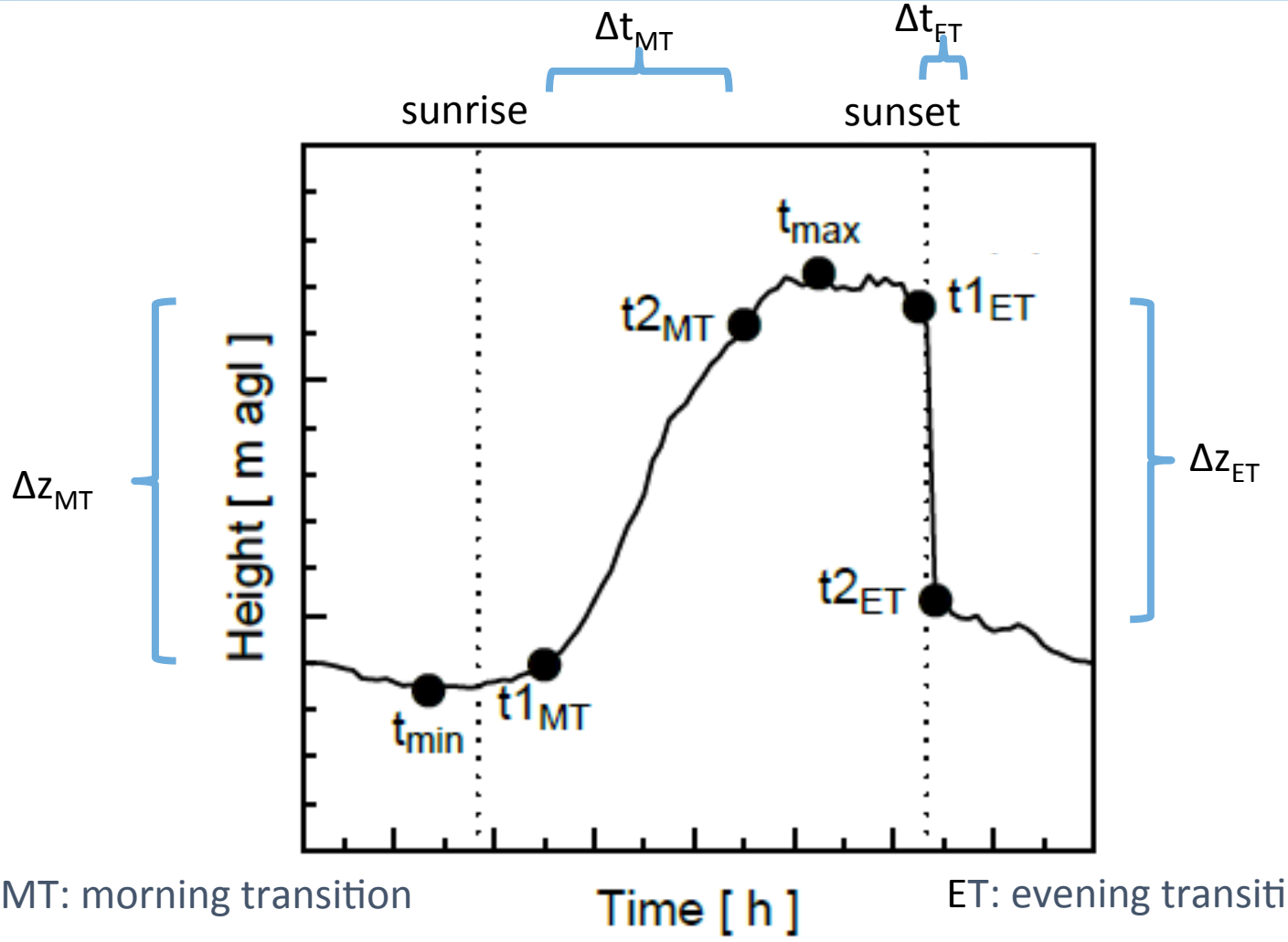
- Pollution events occur in contrasted dynamical situations (high/low wind/MLD)
- Winter pollution events:
  - Continental wind direction (polluted air-mass advection):
    - Low impact of wind speed and MLH on PM2.5 levels
    - PM2.5 variability likely due to source variability and transport conditions ?
  - Oceanic wind direction (clean air-mass advection):
    - High impact of wind speed and MLH on PM2.5 levels
- Dilution (ML growth) has a strong influence on PM concentrations when advection is weak
- Dilution (ML growth) is driven by synoptic processes (thermal inversion) and local processes (surface conditions)

Clean-air advection



Dilution

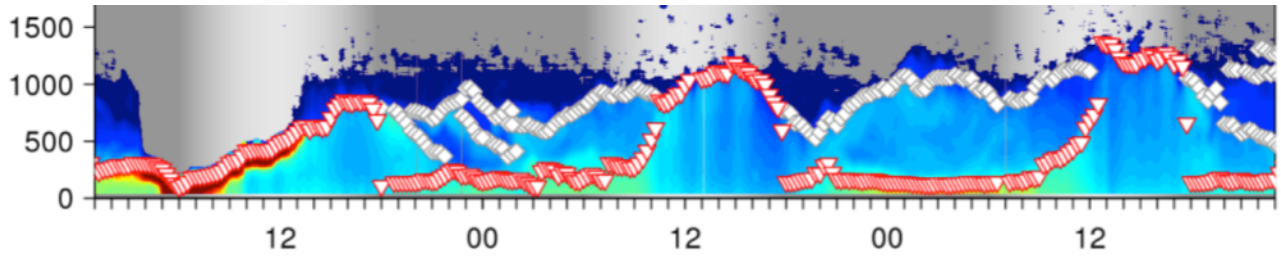
Improving dilution diagnostic



MT: morning transition

ET: evening transition

Vaisala CL31 →

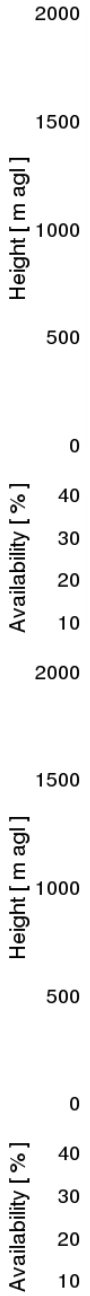


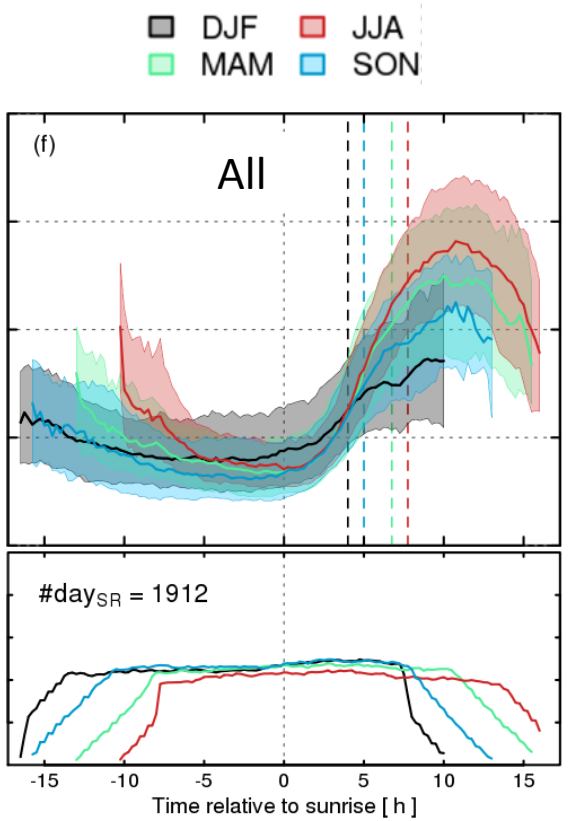
Kotthaus and Grimmond, in prep.

ABL statistics over London

ABL classification based on

- Cloud cover
- Variability of CBH
- precipitation flag
- Z_{ML} in relation to CBH





Kotthaus and Grimmond, in prep.

Future work

Under which conditions does the diurnal evolution of the ABL dynamics (incl. circulation, mixing, dilution, precipitation, clouds, surface forcings, atmospheric stability, role of residual layer …) have a measureable impact on air quality (major components considered to have health implications) in urban environments?

Dynamics:

- Wind / ABLH impact on PM25 and AQI in Paris → apply this to London.
- Diurnal cycle of ABLH for different ABL types (effects of BL clouds, stratiform vs cumulus clouds)
- Future diurnal evolution of the ABL dynamics → measureable impact on air quality

Links with London LAQN

- Comparative studies ABL dynamics depending on ABL type
- Diurnal patterns of ABLH in London (city) vs Paris (city and suburbs), in relation to surface fluxes.
- Can something be learned from contrasts between the two cities?

Thanks for your attention!

‘SPRING’ (may, april and june on 2011-2015):

Wind direction:

- Continental → larger PM values
- Oceanic → mainly low PM values + larger impact of wind speed and MLH