

New air quality insights using ceilometers

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How the boundary layer affects air quality

- Air quality is largely determined by emissions and atmospheric chemistry.
- However local meteorological conditions and especially local boundary layer dynamics play a key role
- The boundary layer :
 - defines the volume where the emissions mix
 - contributes to vertical and horizontal emissions mix
 - brings in long range transportation pollutants such as wildfire smoke
- Already in 2016 WMO declared "*There is a need for higher vertical resolution observations (...) in the boundary layer*" as severe pollution events often take place when local conditions dominate larger scale synoptic weather

New air quality insights with Vaisala ceilometers



CL31/CL51



CL61

New depolarization measurements



Low/High altitude clouds
Boundary layer height



Icing conditions
Precipitation



Volcanic ash plumes
Sand/Dust/Smoke from
wildfires



Environmental protection agencies across the
USA mitigate pollution with Vaisala ceilometers



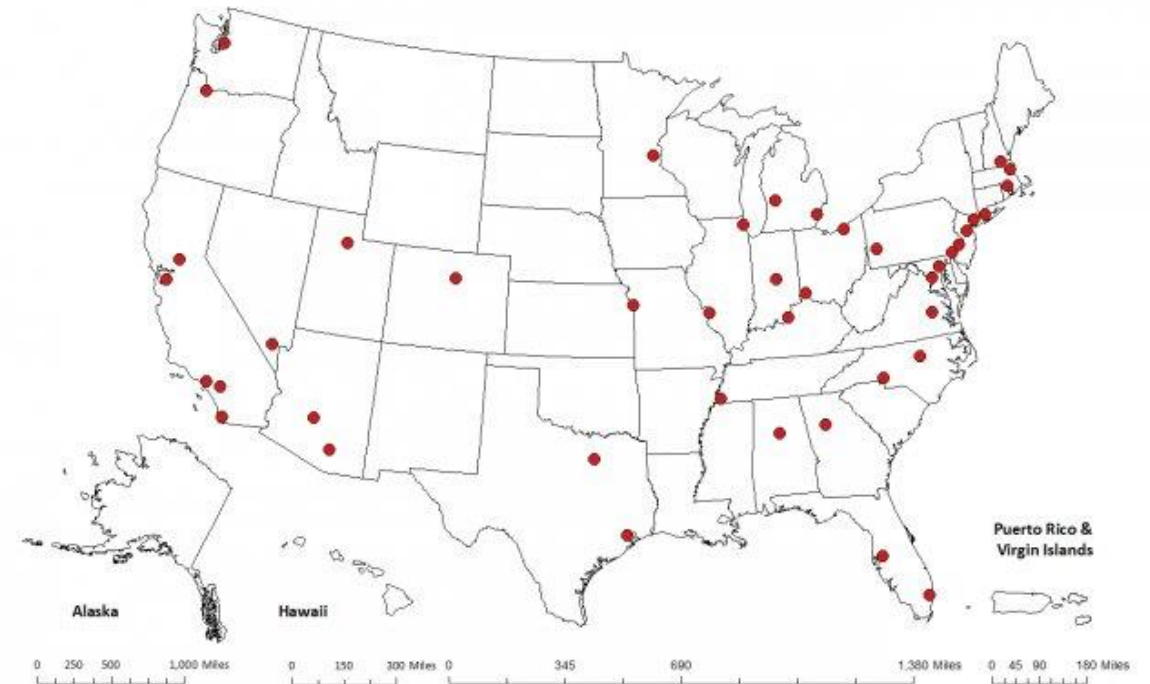
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The challenge : boundary layer impact on ozone concentrations

The U.S. Environmental Protection Agency (EPA) requires to measure ozone precursors in cities with at least one million residents.

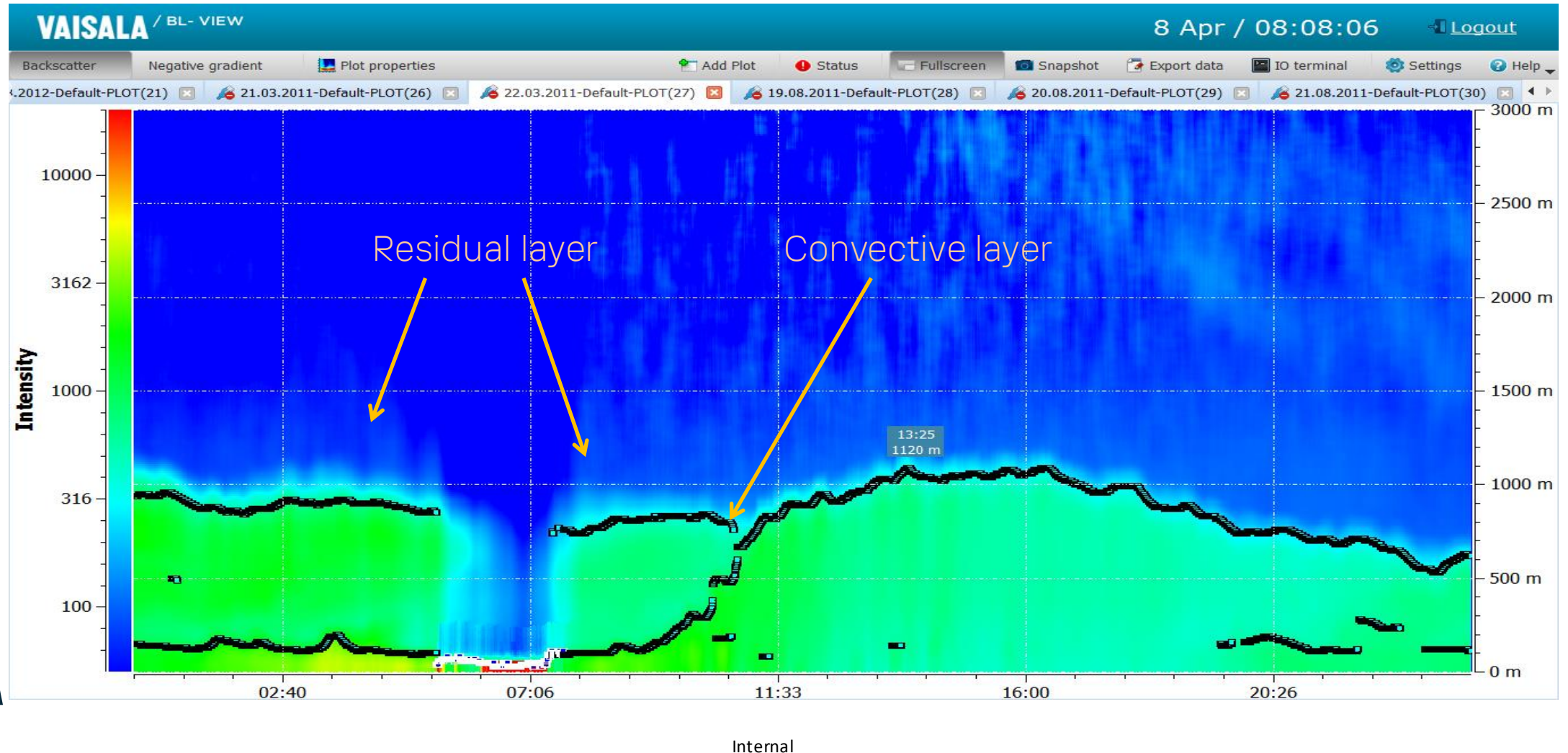
Ozone precursors are primarily found in the boundary layer where air from the surface blends with air higher aloft.

EPA requires accurate detection of the mixing layer height, which is key for determining the volume of the air available for pollutant dilution and forecasting ozone formation.



The solution and the result

More than 70 ceilometers monitor mixing layer height across the USA



Puget Sound Clean Air Agency gains wildfire air quality insights with Vaisala ceilometers



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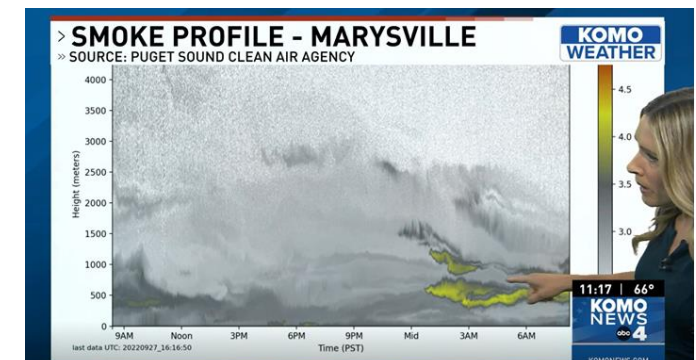
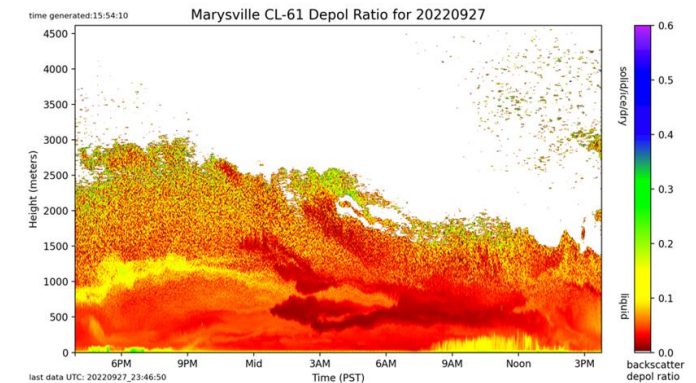
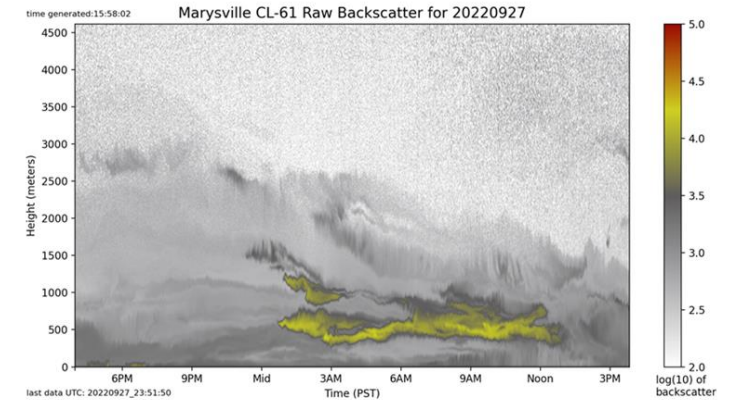
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The challenge : boundary layer impact on wildfire smoke concentrations

- The Puget Sound Clean Air Agency keeps close track of air pollution levels and mitigation measures to protect public health in Washington state including Seattle city
- Many residents use wood burning stoves to heat their homes in winter. Wood smoke contains $PM_{2.5}$, which can be hazardous to breathe in high concentrations.
- There has also been a significant increase in summer wildfires in the surrounding thick forest

The solution and the result

- Puget Sound Clean Air uses several Vaisala ceilometers including the new CL61
- The agency uses this data to look at mixing layer height as well as smoke plumes
- **With this information forecasters can understand the current state of the atmosphere and forecast the smoke mixing down to the surface later in the day.**
- The agency made the 24-hour visualization available for public view on their website and it was featured by a local news channel.



Paris and Berlin adopt Vaisala ceilometers :
ERC Urbisphere



The challenge

- Funded by the European Research Council (ERC), researchers at universities of Freiburg, Reading, Stuttgart, and Forth joined forces to study neighborhood-to city scale atmospheric dynamics and its impacts on citizen exposure and vulnerability
- The researchers aimed to derive urban modifications of boundary layer characteristics :
 - rural vs urban
 - upwind vs downwind
 - intra-urban differences.
- 5 x Vaisala Ceilometer CL61s and 5x Vaisala Ceilometer CL31s provide data about the boundary layer and clouds



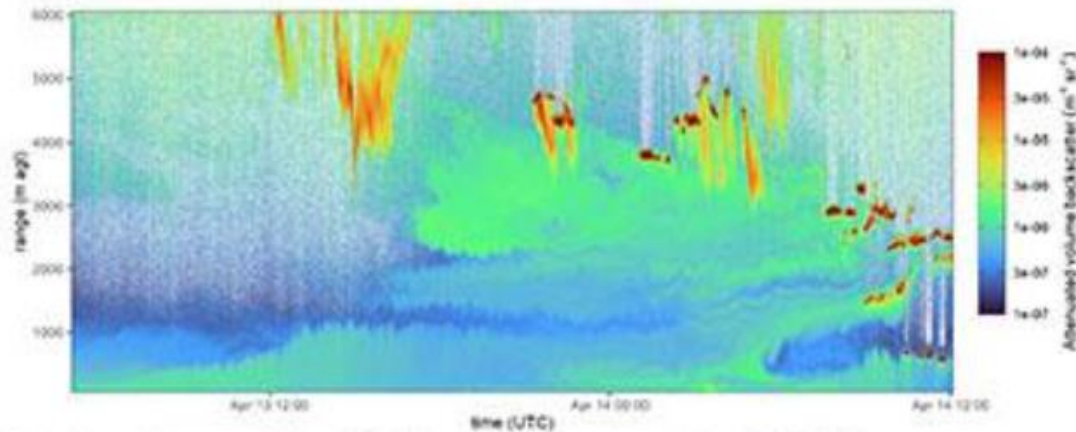
*Mobile Ceilometer CL61 being prepared for measurements in front of a 40 m meteorological tower operated by Technische Universität Berlin.
© Andreas Christen*

The solution and the result

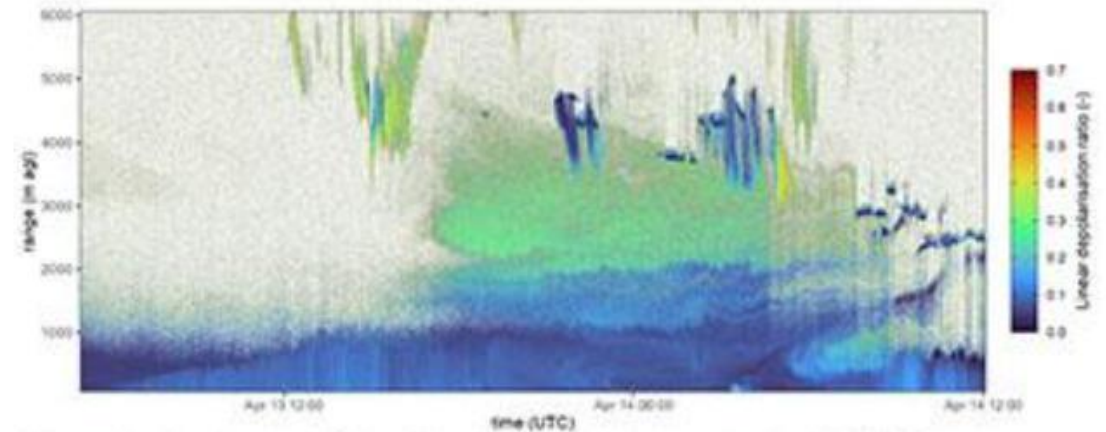
The network has detected :

- Impactful difference in boundary-layer height between urban and rural areas
- Decrease in boundary-layer depth in green areas compared to the built-up environment
- Long range transportation events such as dust plumes originating from the Saharan desert

Ceilometer CL61 boundary layer measurements



Backscatter profile of Saharan dust event, April 2022.



Depolarization profile of Saharan dust event, April 2022.

More to come : a new campaign is conducted in the city of Paris with similar measurement set !

Conclusion

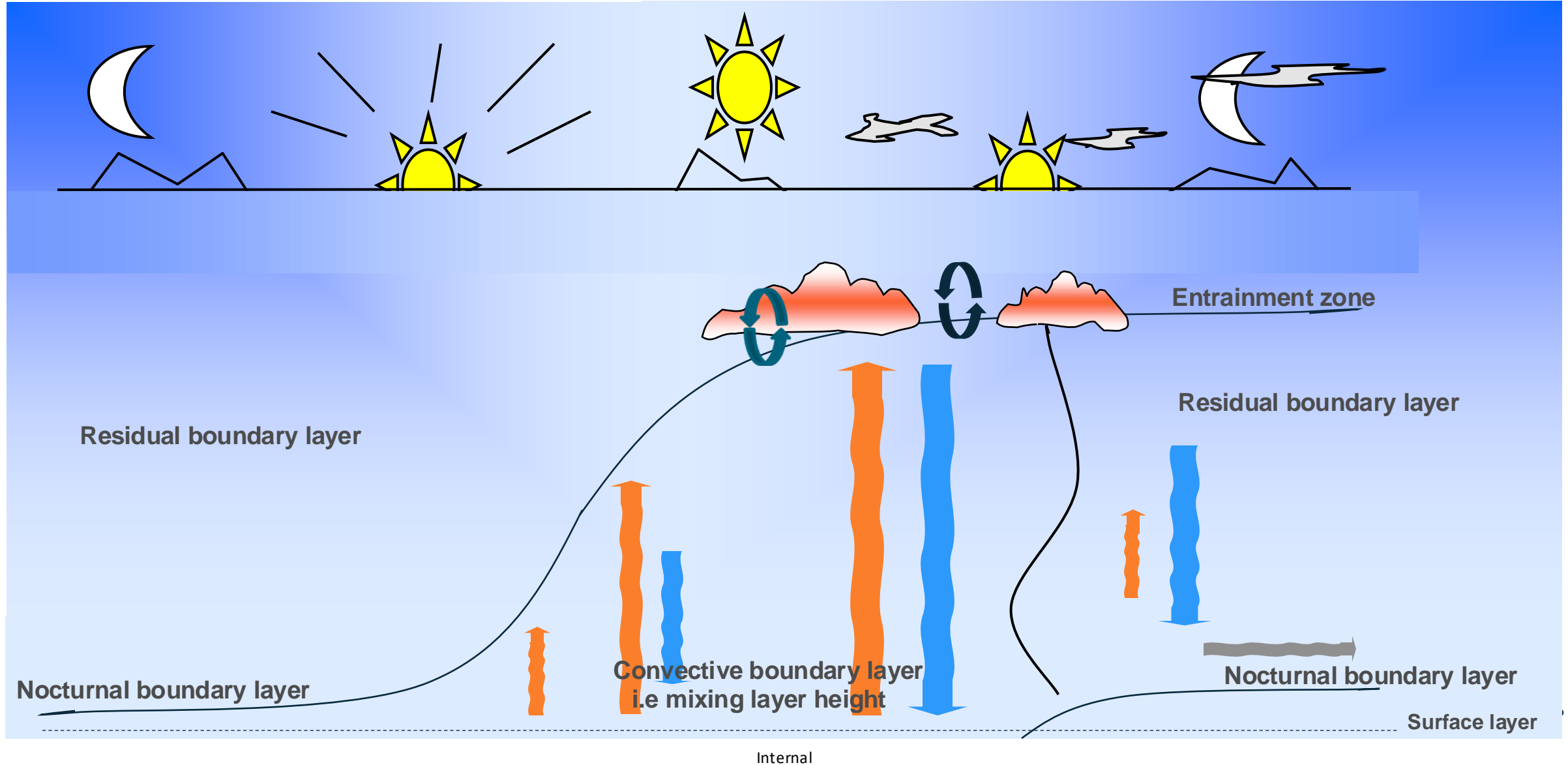
Atmospheric boundary layer dynamics impacts :

- pollutants level
- their travel
- their danger to communities
- A better understanding of local boundary layer dynamics is needed to develop the next generation of weather and air quality models
- The combination of surface and boundary layer measurements, modelling and social sciences, contribute to Integrated Urban Services that address weather, climate, hydrological and environmental processes in cities, impacting day-to-day operations as well as future planning.

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Appendix

What is boundary layer and its impact on air quality ?



What is Depolarization?

Spherical scatterers

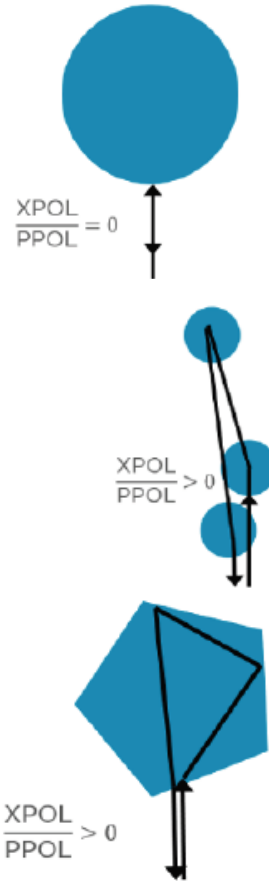
Due to the symmetry of the scattering event, the detected return signal is not depolarized.

Multiple scattering

Can cause depolarization even when the scatterers are spherical.

Non-spherical scatterers

Cause significant depolarization due to multiple internal reflections at solid-air interfaces



- Lidar ceilometers emit linearly-polarized laser pulses.
- When a portion of this light scatters back towards the instrument, the polarization direction may change.
- This depolarization depends strongly on scatterer shape, orientation, and laser wavelength.

More information with depolarization

