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WHY DO WE NEED TO CHANGE THE AIR QUALITY INFORMATION INDEXES TO A HD MAPPING APPROACH ?

Accumulation: a more realistic approach to the state of the atmosphere than the maximum

Air quality information indicators around the world all use the same calculation principle: the maximum wins. The calculation method is relatively simple. A quality scale is defined for each pollutant in the index, giving a sub-indexe per pollutant. The index is given by the **highest sub-index (maximum rule)**[1].

The foundations of this method were laid **more than thirty years ago, to provide global information.** In France, the Atmo index is one of the major advances of the 1996 Law on Air and Rational Use of Energy (LAURE). However, the information produced needs to be put into context. Monitoring is patchy and takes the form of a number of regulatory measurement stations, not all of which monitor the same pollutants. The goal is to translate this information into an accessible way of describing the air in a city. The development of monitoring systems, incorporating complementary approaches (regulatory measurements, sensors, modelling, reports, etc…), now produces a finer spatio-temporal assessment of the atmosphere : **HD mapping**

The **knowledge acquired** and the importance **of digital information services** make us reconsider the development of these indexes, so that we can **better map the state of the atmosphere and, above all, link them to local-individual actions (health-behaviour).**

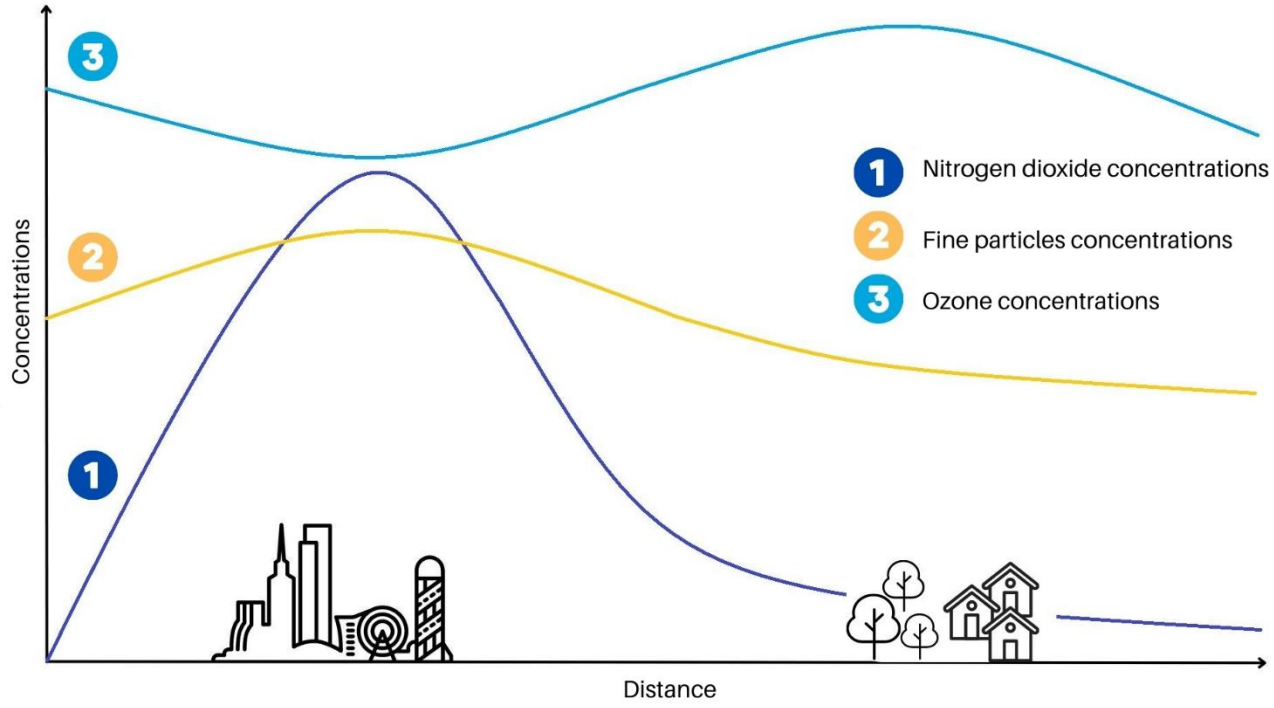
The following development will address :

- **The contribution of an index based on accumulation rather than the maximum** to produce HD maps, the first operational translations of which are the ICAIRh and ICAIR365 indexes developed by AtmoSud.
- The ability with the cumulative index to add new pollutants, such as **ultrafine particles or specific local pollutants (industrial, agricultural, etc…)**.
- A necessary **evolution for the ozone sub-index.**

[1] Example with the European Index or the French Atmo Index: https://airindex.eea.europa.eu/Map/AQI/Viewer/

A cumulative index better suited than the maximum to produce high-resolution maps

Accumulation rather than the maximum is a proposed change that will ensure that the index remains easy to read and to understand. This proposal is based on a simple idea : **some pollutants have antagonistic behaviours** (NO_2 and ozone) even though they belong **to a common, complementary cycle** (it is the photodissociation of NO_2, which is the basis of a major part of photochemistry and in particular the production of tropospheric ozone). In addition, fine particles (PM10 or PM2.5) provide further information, due to the diversity of their origins (wide range of sources and secondary production). The sub-indexes (variable) behave relatively independently, **each providing a complementary information.**



Representation of nitrogen oxides, fine particles and ozone concentrations over a summer day in urban, peri-urban and rural areas..

It is clear that accumulation better translates at high-resolution **the notion of pollution cocktail and state of the atmosphere**. It provides **genuine spatial and temporal variability**, reflecting the evolution of pollution in space and time. This information contrasts with the relatively **flat cartographic information produced by indexes based on the maximum**. In the latter case, the information is most often provided by one pollutant, ozone, whose spatial variability is low.

Accumulation makes it possible to link information more directly to activities and actions whether on short time scales (hourly) or on a chronic basis (annual). Approaches to the concept of cocktail of pollutants in **health studies are generally based on accumulations** (cumulative Health Risks Studies for example). The **development of digital services** to support decision-makers and citizens in taking actions to preserve the air lends itself better to this new approach than that of the maximum. This new method also makes it possible **to add specific pollutants** (industrial, agricultural…) in a readable way, without distorting the information based on regulated pollutants.

ICAIR – New cumulative air index

AtmoSud has established three cumulative indexes that meet the main expectations for information and digital services. The aim of HD cartographic information is to go beyond mere observation and to support the development of uses, practices and decisions. Those indexes are resolutely geared towards local action and decision-making:

ICAIR24

ICAIR24 – Cumulative air index for the 24 hours of the day

ICAIR24 – Cumulative air index for the 24 hours of the day – It is based on the reference scales of the European index, just like the French Atmo index. It offers an evolution of the Atmo index with a finer spatial resolution than the municipality. These daily indexes are widely used by the media and applications to provide a global information on a finer scale (e.g. a school group).

ICAIR365

ICAIR365 – Cumulative air index for the 365 days of the year

It provides annual information based on World Health Organisation guidelines, which European standards aim as long-term objectives. This index reflects people's chronic exposure to outdoor air pollution. It is geared towards all types of audiences, particularly for recurring questions about housing development, activities… It is also intended for local actors and decision-makers. Those cumulative index maps answer questions regarding priority action areas (low emission zones, school streets, etc.) and territorial development (school implantation, sports fields, etc.)

ICAIRh

ICAIRh – Hourly cumulative air index

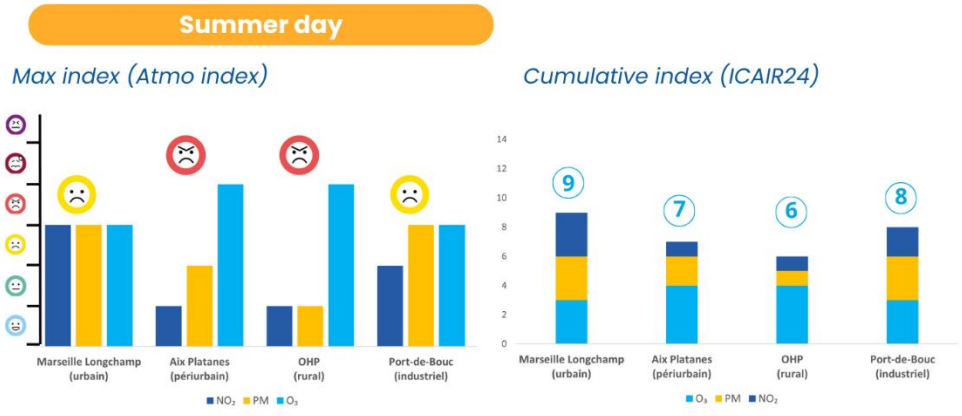
It is based on the reference scales of the European index. ICAIRh provides a fine spatial and temporal information that answers questions from daily life. It is designed to support changes in practices to better protect people from air pollution, by providing a clearer picture of areas where air quality varies in space or time. This is undoubtedly the best index for producing digital services linked to the protection of the most vulnerable people, supporting sporting activities or any activity in which air should be integrated. The ICAIRh index, which is close to day-to-day life, aims to encourage people to take air into account in their daily lives.

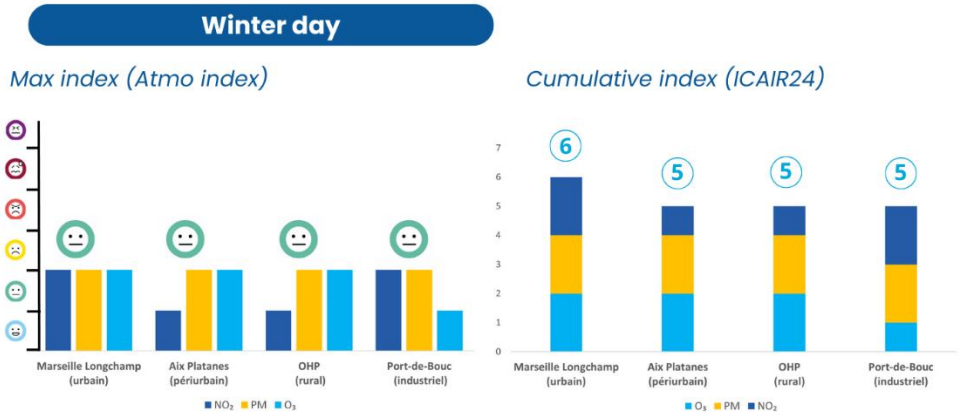
ICAIR24 – Daily cumulative air Iindex – based on European index thresholds.

The daily cumulative air index is based on the **Atmo index scales.** For the 4 pollutants (NO_2, O_3, PM10 and PM2.5), **ICAIR24** determines sub-indexes ranging from good (equal to 1) to extremely poor (equal to 6). To produce an index that aggregates the pollutants over the course of the day, AtmoSud suggests **adding these sub-indexes together**. To avoid double counting particulate matter, only the most penalising sub-index between PM10 and PM2.5 is retained. Thus, in a situation where the levels of **NO_2, ozone and particulate matter are all moderate, the daily index would be equal to 9**, whereas the max approach would give an index of 3 (poor).

Thanks to the cumulative index, we get a more refined approach to air pollution. In the example below, we can see that, with the maximum approach, the urban site of Marseille Longchamp has an air quality index of 3 (poor). With the cumulative approach, the same site obtains an index of 9.
On the same day, the OHP rural site had worse air quality (bad) than the Marseille Longchamp site (poor). With a cumulative approach, OHP's air quality was better (index of 6) than that of the urban site (index of 9)

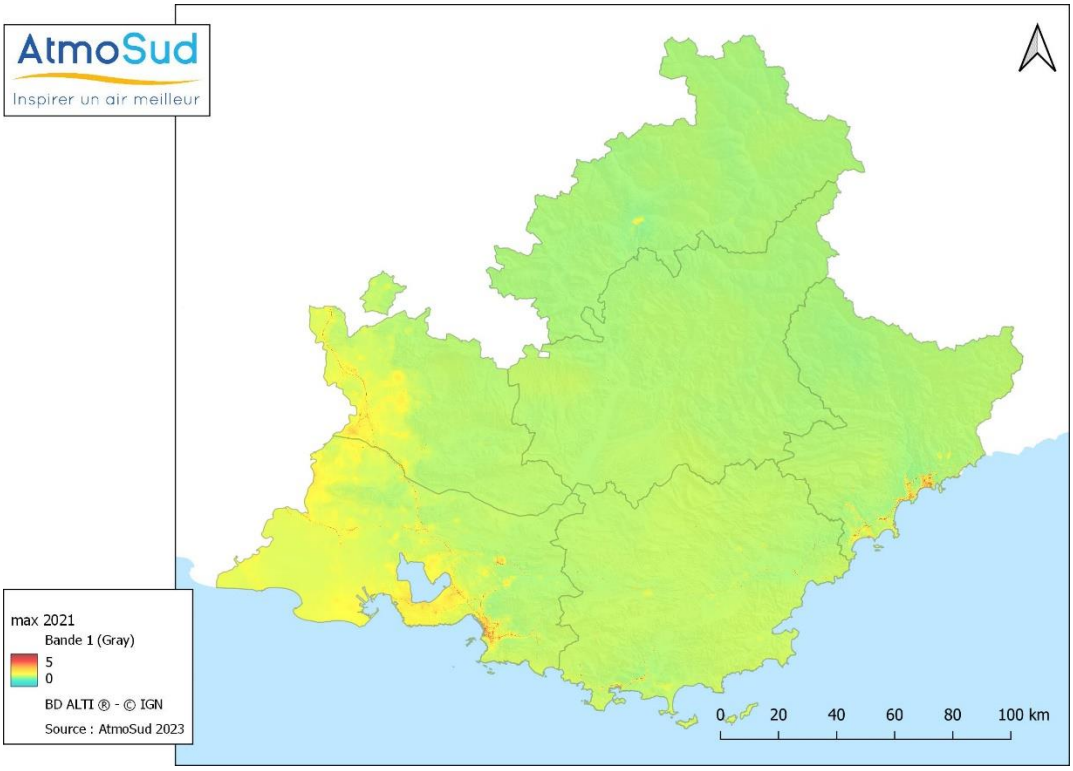
Why should this be? **Because with ICAIR24, the most penalising pollutant in the maximum approach is no longer the sole marker for qualifying the air; it is the sum of the sub-indexes that will make it possible to qualify the air that people breathe.**

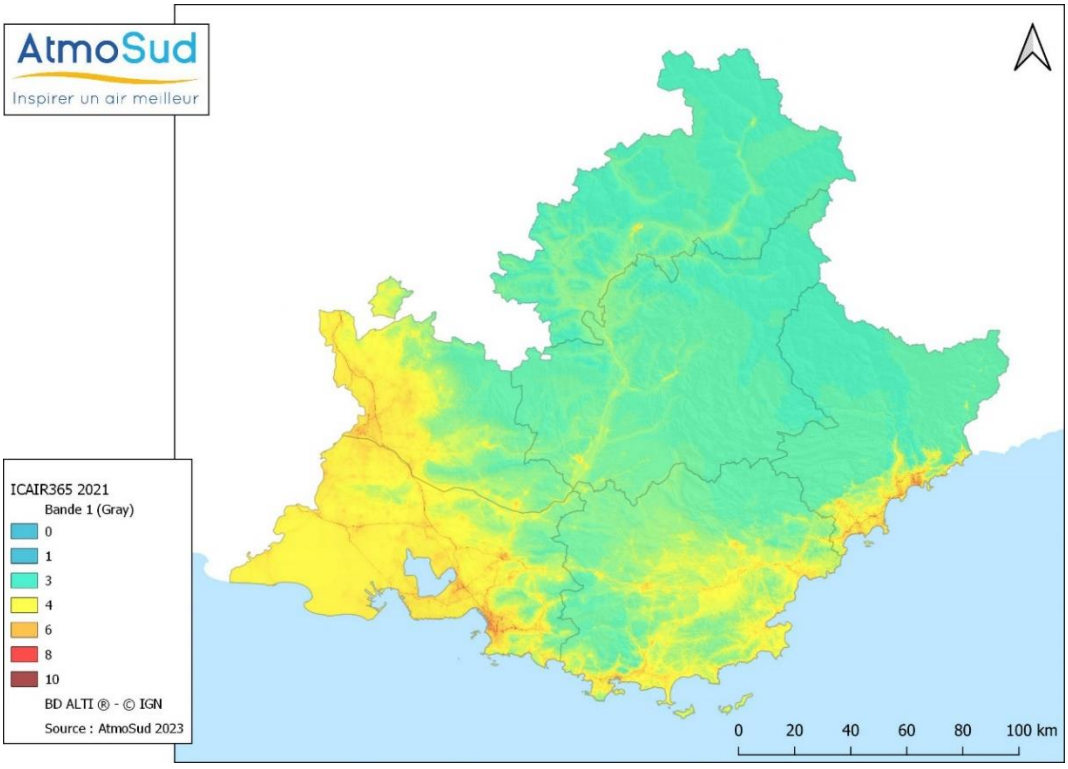




ICAIR365 – Annual cumulative air index – based on WHO guidelines

The same calculation principle has been adopted to produce a cumulative annual index. It is based on **WHO guidelines.** Each $ICAIR_{365}$ increment of **one point** corresponds to **a guideline (GL) being exceeded**. For example, an $ICAIR_{365}$ value of 3 corresponds to 3 times a guideline being exceeded. This service is accessible on the homepage of the AtmoSud website (Year Tab)





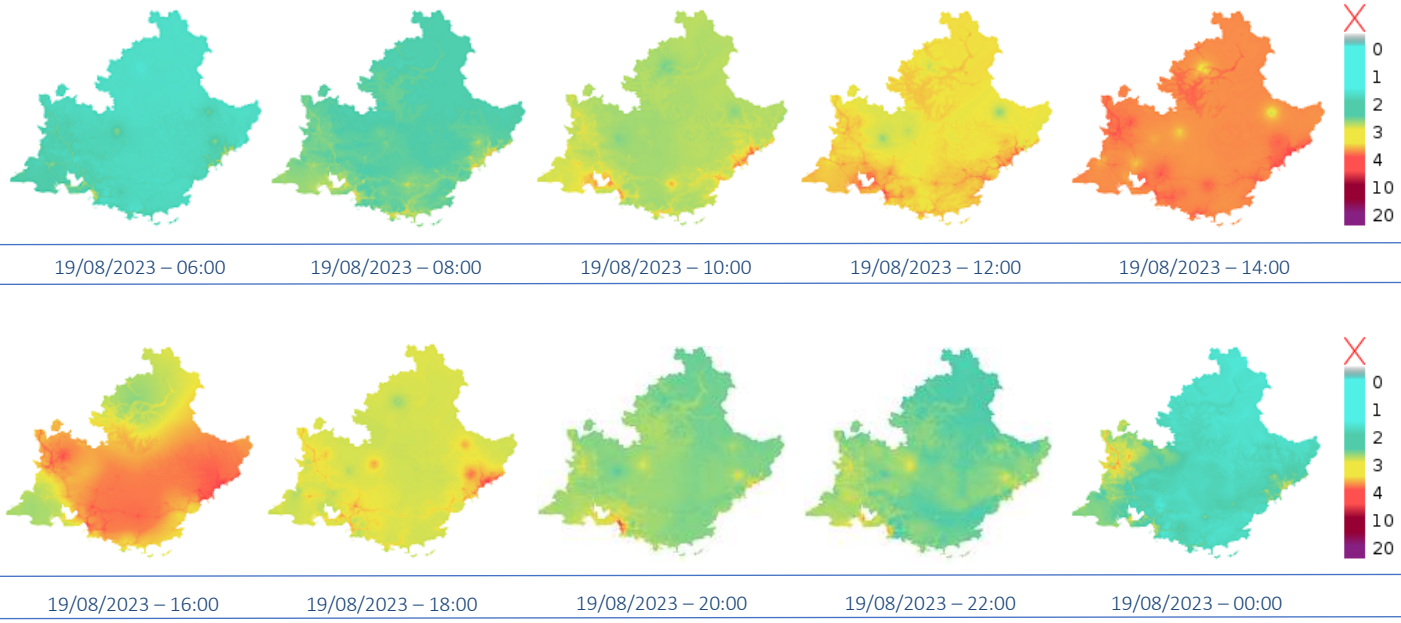
At the top, a max index map (PM10, PM2.5, O_3, NO_2 standardised by their annual WHO GL). At the bottom, a cumulative ICAIR365 index map. The cumulative map shows more spatial variability around urban areas and human activities than the max index map.

ICAIRh – Hourly cumulative air index – based on European index thresholds

The cumulative hourly index compiled by AtmoSud is based on the **quality scales of the European index** (European Environment Agency). For PM10 and PM2.5, ICAIRh uses an **hourly scale** based on a linear correlation between the 24-hour average and the hourly value. In France, the relation is **a factor of about 2**. With the elements discussed above, these indexes could evolve to improve the clarity and quality of the information.

The high-resolution mapped indexes open up new perspectives in terms of links to **action, local or individual decision-making, and health approaches.** The closer link **with activities** means that **new digital services can be considered to integrate air into daily habits,** with a more integrative view. ICAIRH is currently produced for each hour at a spatial resolution of 25 metres in the PACA region. These maps take into account **regulatory measurements (from monitoring sites), model outputs and contributions from public sensors. This service is now operational on the AtmoSud website :** www.atmosud.org

Hourly map – ICAIRh index – 19th August 2023



Addition of pollutants to the index (UFP, industrial, agricultural pollutant) to provide a more realistic information on the state of the atmosphere.

Fine and ultrafine particles.

The routine measurement of ultrafine particles (UFP) is profoundly changing the way particles are characterised. The historical mass-balance approach (PM10, PM2.5) makes the largest particles predominant while underestimating the very fine ones (1 particle of 10 µm = 1 million particles of 0.1 µm in mass). This explains why, with advances in vehicle filtration, particle measurements have little correlation with nitrogen oxides and therefore with combustion.

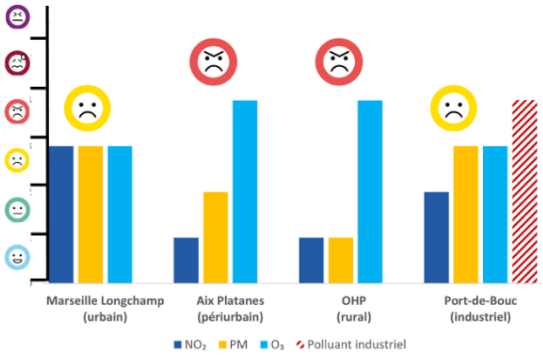
UFPs (<0.1µm), measured in numbers, show that the quantity of particles remains very significant close to roads or in industrial or shipping plumes. It should be noted that near **airports**, UFP levels can also be very significant, even though the other regulated compounds (nitrogen oxides, PM) have a more limited impact.

Even though particles are involved in both cases, these are two **complementary informations** that should eventually be included in the information disseminated in the long term. In France, the direction taken by the Ministry of Ecology to develop this monitoring since 2021 should facilitate this integration.

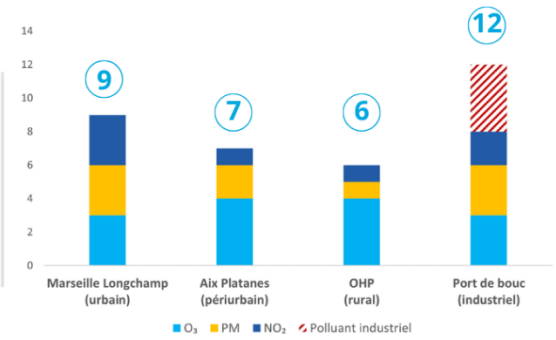
Today, in **agricultural areas or industrial sectors**, the regulatory indexes do not accurately represent the state of air quality. The **principle of adding specific local pollutants (1,3 butadiene, dichloroethane, pesticides, UFP, etc…), in cumulative mode**, is very easy to read and provides valuable information. Work on quality scales is a necessary step, and could be the subject of national or European projects. The **link with indoor air** should also be considered, as our exposure is a continuum).

Summer day

Max index (Atmo index)

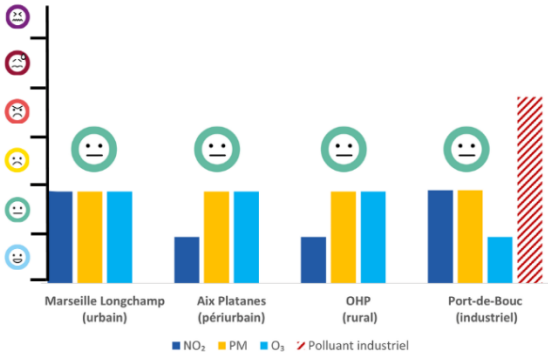


Cumulative index (ICAIR24)

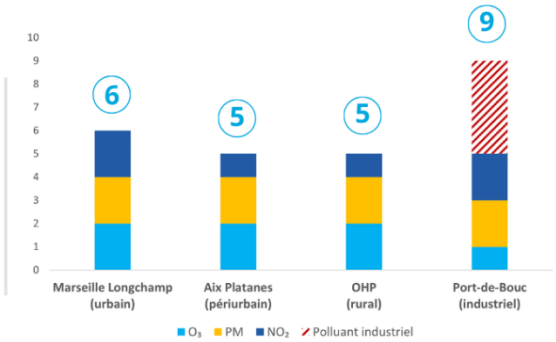


Winter day

Max index (Atmo index)



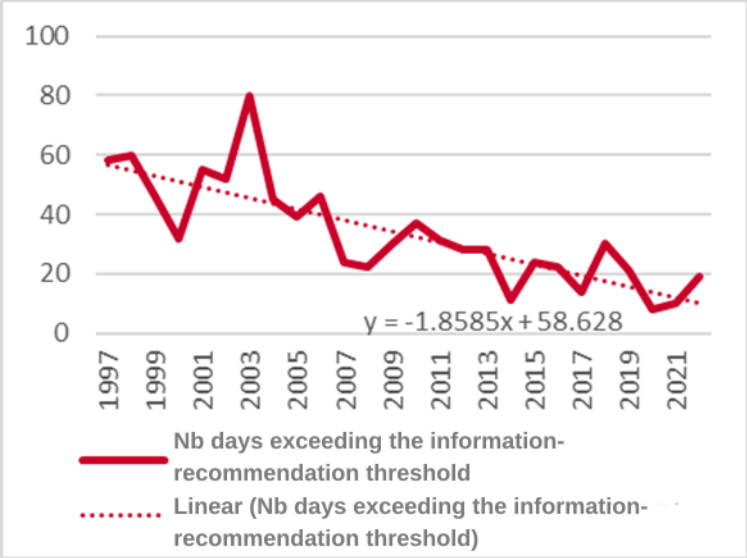
Cumulative index (ICAIR24)



A necessary evolution of the ozone scale

In the Provence-Alpes-Côte d'Azur region, **ozone gives the Atmo index 95% of the time, summer and winter alike**. Yet, it only accounts for 10% of the overall health costs of air pollution[2]. Besides, the municipal Atmo index is, **on average, worse over the year in rural areas than in the centres of major regional cities** (Marseille, Toulon, Nice, Avignon) which evidently does not accurately reflect the spatial variability of pollution. This situation seems to be fairly widespread in France.

It is proposed to change the **ozone scale** in Europe and France to better distinguish:



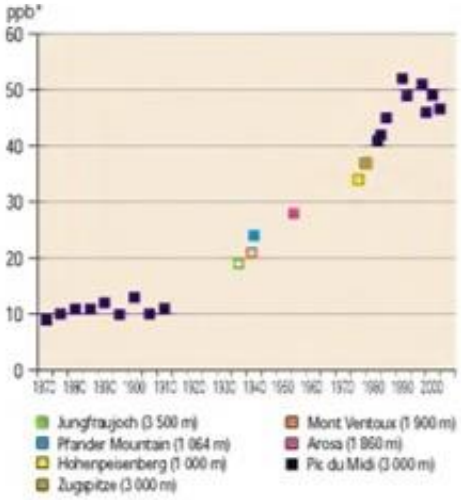
- **active photochemical pollution**, in which ozone is an indicator of the presence of many other compounds,
- situations where its presence is **relatively isolated** reflecting the level of the **free troposphere.**

This clearer distinction links more directly with **local action**, as the fight against precursor emissions translates today in a **real lowering of photochemical pollution**. The graph opposite illustrates the trend in the number of exceedances of the European information threshold of 180 µg/h, clearly showing the decline in the intensity of photochemical episodes and therefore the gains attained thanks to the actions to reduce regional precursors.

The **level of the free troposphere**, after rising sharply during the twentieth century, **tends to remain relatively stable in Europe**, due to long-distance transport, mainly from Asia (transcontinental), **which offsets the decrease in production in France and Europe**. The lifetime of ozone in this atmospheric layer is **around twenty days**. Free tropospheric ozone, resulting from long-distance transport, or present outside local photochemical pollution episodes, **is not associated with the other chemical species observed during photochemical episodes** (free radicals, ultrafine particles…) The simple contribution of tropospheric ozone (excluding local production) therefore reflects a very different state of the atmosphere, with **much less pollution**.

Note : ozone is also a major greenhouse gaz. Its radiative forcing comes third after carbon dioxide and methane.

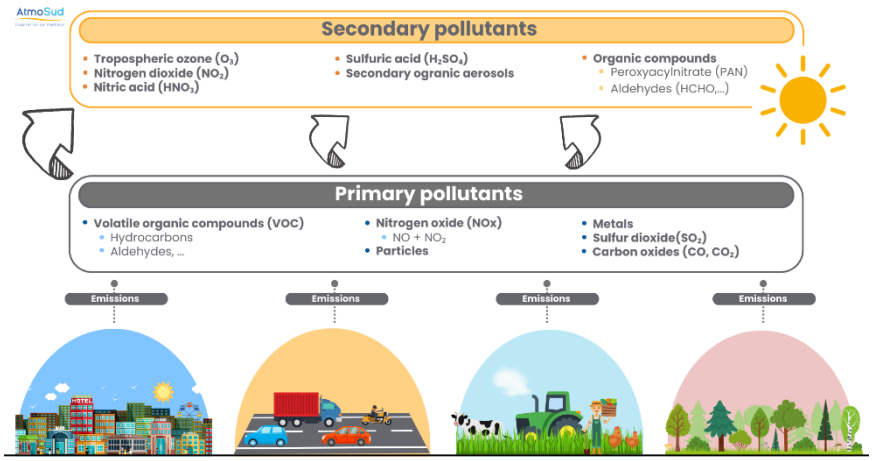
Evolution of ozone concentrations on high-altitude sites in Western Europe (1870-2022)



* ppb : partie par milliard (billion).

Source : Laboratoire d'Aérologie, Toulouse.

[2] According to figures from the European Environment Agency, in France in 2019, 65% of the years of life lost because of air pollution were due to fine particles, 23% were due to NO_2, and 11% were due to ozone.



Photochemical episodes, which result in the presence of **numerous oxidising pollutants and an increase in ultrafine particles**, only occur from April to the end of September and not every day, as atmospheric stability is a key factor.

The maximum approach and the first level of the European scale (change from good to average) do **not make it possible to distinguish between these two situations** and lead, even at the heart of winter, to the production of more degraded indexes in rural or outlying areas. Anecdotally, the upward trend in ozone levels observed at urban sites merely reflects the drop in NO emissions, and therefore, a lesser pollution. The cumulative mode provides the beginnings of an answer and partly corrects the majority approach, which distorts the reality of the pollution situation.

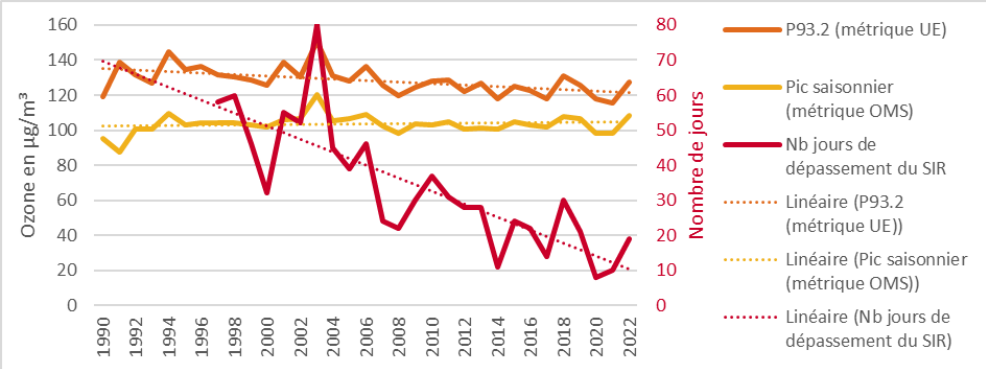
The maximum approach and the choice of the first level (good/average at 50 µg/m^3) mean that the ozone index **overwhelms the information in a somewhat unfounded way for a large part of the year.** As indicated above, ozone gives the Atmo index in Provence-Alpes-Côte d'Azur, even at the heart of winter, in all situations. The levels then reflect, a **vast majority of the time,** that of the free troposphere (large scale). Levels of other pollutants outside area sources are generally low. The spatial representation, insofar as ozone is predominant in the current index, **does not accurately reflect the state of the atmosphere**. This leads us to consider rural sites, which are objectively the least polluted, as sites with **"average"** or **"poor"** air quality most of the time. As indicated in Provence-Alpes-Côte d'Azur, the frequency of the poorest Atmo indexes **qualifies rural municipalities.** They are rated more poorly over the year than town centres or industrial areas.

Winter background levels in rural areas have been around 60 µg/m³ during the day throughout France for more than 10 years. The first thresholds of the index should necessarily be above this value.

On an hourly scale, the **EPA's (US Environmental Protection Agency) ozone sub-index** seems more consistent and would make it easier to distinguish between these two **situations (108 µg/m³**). Note that the **WHO 8-hour** guideline **is 100 µg/m³ .**

A value of 100 µg/m³ over one hour could be a good compromise.

With regard to the chronic approach, the use of a percentile **(93.2 of daily 8-hour averages, for example, the European target value)** makes it possible to distinguish more clearly between changes in local photochemistry (generally decreasing in France and Europe) and the large-scale approach (transboundary transport of ozone).



Ozone trends according to different indicators (PACA regional average, source: AtmoSud)

ICAIR, a cumulative air index adapted to both expert and general public communication and geared towards digital technology

The principle of an index calculated on the basis of the sum of the pollutants rather than the highest sub-index means:

1. A better representation of atmospheric pollution phenomena
2. An easier communication with the public
3. Linking the index with levers of action

The cumulative index provides contrast and spatial variability, highlighting the various sources of pollution. Air quality is not the same on a main road, in its vicinity or in a park. A cumulative hourly index reflects temporal variability. In summer or winter, the most polluted hours are not the same. Restoring this variability means giving citizens the means to adapt their activities to the pollution, and giving politicians concrete information on the levers of action (impact of traffic peaks, use of wood-burning heaters, etc.).

For digital applications and uses, the spatial and temporal variability of the index, on an hourly scale, are strong assets. Offering a large-scale index over a single day does not make it an everyday tool. ICAIRh can be used to provide advice for day-to-day activities (sporting activities, going out with children, advice for sensitive people), which is what the applications are all about.

Flows, APIs and ICAIRh can thus be taken up and contribute to the circulation of useful, science based, large-scale information on air quality.