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Tropospheric ozone and air circulation in the mountains of South East France

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Tropospheric ozone has become a major pollutant of rural and mountainous areas where its toxic effects have been noted to attack subalpine forests of the Mercantour National Park near Nice, France. These forests are mainly constituted by Larix Europaea, Pinus Cembra. The presence of ozone has been confirmed by an air quality surveillance network which monitors levels continuously, and by a series of experiments using passive captors.

The concentration of ozone in the air depends on in-situ chemical reactions of primary pollutants and on processes occurring at a distance since primary pollutants or ozone itself can be transported over considerable distances. In all situations, air circulation plays a very important role since it is responsible for the advection and displacement of gases emitted mainly from automobiles in our case. The mountains in the region of Nice in South East France are characterized by their altitude (more than 3,000 m at the Italian border), low population density and a network of fairly rectilinear valleys extending down to the sea located at a distance of about 50 to 70 km from the highest peaks. In contrast, the coastal area of the “Côte d’Azur” has a high population density with more than 1 million inhabitants living on a strip extending about 50 km along the coast and 10 km inland.

In the mountains, there are therefore two potential sources of ozone which can have a cumulative effect : that produced in-situ during favourable climatic conditions (summer heat, intense solar radiation) using hydrocarbons emitted by the forest, and more importantly, the ozone produced from primary pollutants produced in the “Côte d’Azur” (or farther) located tens of km away.

The transport of pollutants from the coast inland was the objective of a study undertaken in 2003 in the context of the European Interreg Program “Formed Ozone.” The method consisted of making measurements of wind speed and direction using tracers during periods of high ozone concentration in the mountains (measured at an altitude of 1,500 m).

Two types of tracers were used :

1- latex balloons that provide qualitative information on air circulation in the first 300 m to 400 m based on the monitoring of their speed of rise and lateral displacement after launch.

2- “mylar” non-deformable constant pressure balloons that rise to a height where the external air pressure equals internal balloon pressure. These balloons are also called C.L.B. (Constant Level Balloons). In such a case, the balloon induces no motion of itself and behaves like a visible air bubble. After launching, the balloons can be monitored in strategic locations (crests) using a theodolite and telemetre, or followed up valley over distances as great as 10 km or more, using a car.

Air circulation during the summer season is due mainly to thermal breezes and not synoptic conditions. This is due to a combination of frequent high pressure systems, low pressure gradients, and frequent days without cloud cover (high solar radiation) on the region. A diurnal cycle is put in place where air circulates up valley during the day (sea and valley breeze) and seawards at night (land and mountain breeze).

Dozens of measurements carried out in different places of Mercantour National Park mountains, using the balloons described above, demonstrated that the usual daytime breeze coming from downstream side is an efficient means of drawing air from the coastal area and transmitting it inland to the highest peaks. Exceptions to this cycle arise during the rare conditions when synoptic winds are established in the boundary layer, or during the eruption of convective storms, which disorganise the thermal breezes.

More, ozone concentrations in Nice and in the mountains are highly correlated when a 2 hours lag time is allowed showing a clear relationship between the source of the pollutant and its displacement inland by thermal breezes.

In conclusion, we can presume that the primary source of ozone measured in the mountains has its origin in the urbanised coastal area. Now that the role of air circulation has been established, a chemical pollutant model is needed to partition the amount of ozone produced from forest and that produced from automobile emissions

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