

Balloon-borne sample analysis of organic compounds present across atmospheric layers ranging from the troposphere to lower stratosphere

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Abstract

Atmospheric aerosols play an important role in the Earth's climate system. We present the analysis of atmospheric molecules/particles collected with a sampling system that can fly under regular weather balloons. The flights took place on 10 October 2022 from Reims and on 13 December 2022 from Orléans (France). The samples collected on activated carbon filters were analyzed by high-resolution mass spectrometry (Orbitrap Q-Exactive). Using Desorption electrospray ionization (DESI), we could derive hundreds of chemical formulas for organic species present in different layers from the troposphere to the stratosphere (up to 20 km). Measurements of O₃, CO, and aerosol concentrations a few hours before these flights took place to contextualize the sampling.

Chemical analysis of samples taken at different altitudes shows, in addition to a common set of chemical compounds, significant differences in the number and size of organic species detected. This finding must reflect the unique composition of the atmospheric layers, but also a common pattern of organic compounds. In the tropospheric samples, we found significant oxidised and saturated components, with carbon numbers below 30, which could be explained by complex organic chemistry originating from local and distant emission sources. In samples from the upper troposphere and stratosphere, we detected chemical formulae with higher carbon numbers ($C > 30$). Significantly lower unsaturation numbers were observed in the compounds collected in the stratosphere, which could be the result of UV radiation.

The multimodal distributions of carbon numbers in chemical formulas observed between 15-20 km suggest that oligomerization and growth of organic molecules may take place in aged air masses of tropical origin that are known to carry organic compounds even several km above the tropopause where their lifetime significantly increases.

Overall, these results are consistent with the injection of fire smoke months before the in-situ observations and with thermodynamics inherent to conditions prevailing in the stratosphere

This new analysis method meets the requirements of balloon flights in terms of flexibility and cost.

