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Balloon-borne lidar observations of tropical cirrus clouds

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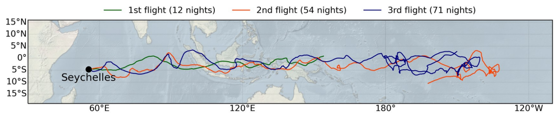
Tropical cirrus clouds have a significant impact on the climate, modulating both the Earth's radiative budget and the amount of water vapor transported to the stratosphere. Observing those clouds remains a challenge as their optical depth covers several orders of magnitude. In the framework of Strateole-2 project, three microlidars have been flown in the lower tropical stratosphere onboard super-pressure balloons, providing high-resolution observations of tropical clouds with an unprecedented sensitivity to very thin cirrus.

Strateole-2 project

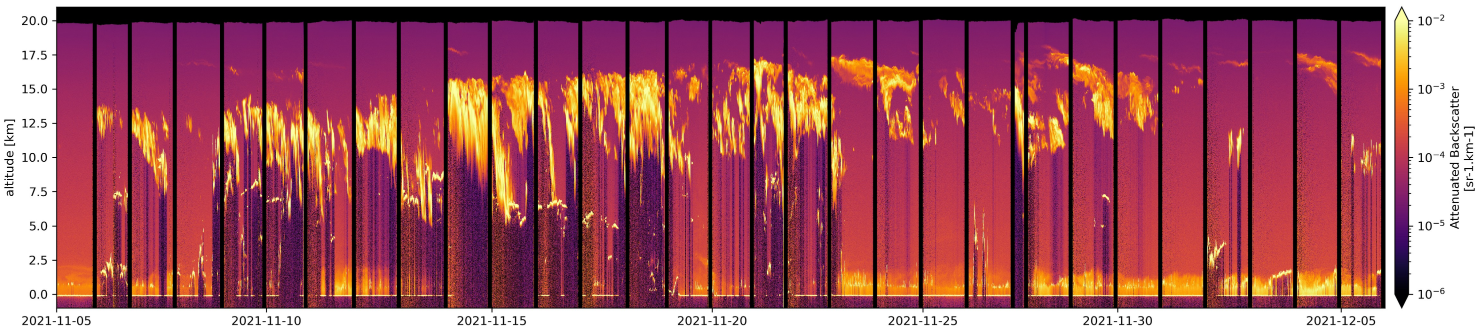
- in situ and remote sensing balloon-borne observations of the Tropical Tropopause Layer (TTL)
- long duration super-pressure balloons flying at targeted levels (~20 km) for several weeks
- balloons released from Seychelles Islands, drifting with the wind along the equator
- first scientific campaign : October 2021 – January 2022, 17 balloons, 3 with BeCOOL on board

BeCOOL : Balloon-borne Cirrus and convective overshOOt Lidar

- light-weight, low-power lidar operating in the extreme conditions of the lower stratosphere
- elastic backscatter, single wavelength of 802 nm, no polarization channel
- nighttime observations only, temporal resolution of 1 min, vertical sampling of 15 m
- clouds' optical depth retrieved from 10-minutes averaged profiles
- Strateole-2 first scientific campaign: 137 nights of observation, ~40 000 lidar profiles



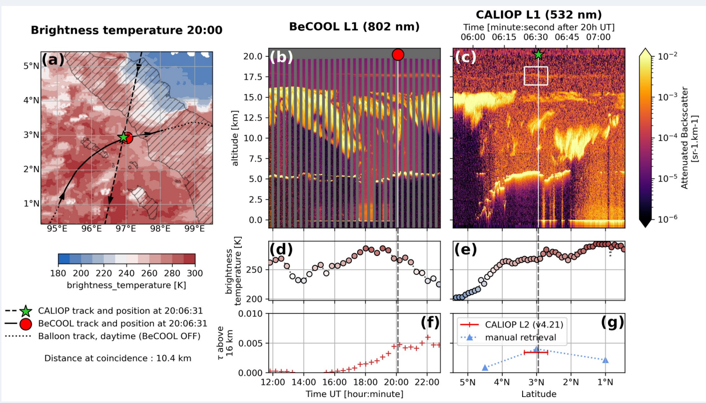
Balloon tracks of the 3 BeCOOL flights during Strateole-2 first scientific campaign



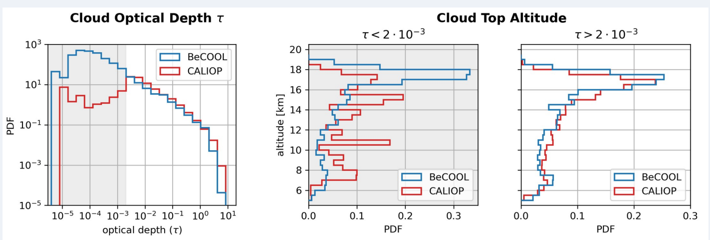
Example of lidar curtain (time vs altitude) of attenuated backscatter, 30 nights of the second BeCOOL flight

Extensive coverage of ultrathin TTL cirrus clouds

Comparisons with space-borne lidar CALIOP highlight the unique sensitivity of BeCOOL to ultrathin cirrus, both from case studies of collocated observations and from a statistical point of view. 23% of BeCOOL profiles exhibit TTL clouds (above 14 km) that are below the detection capabilities of CALIOP.



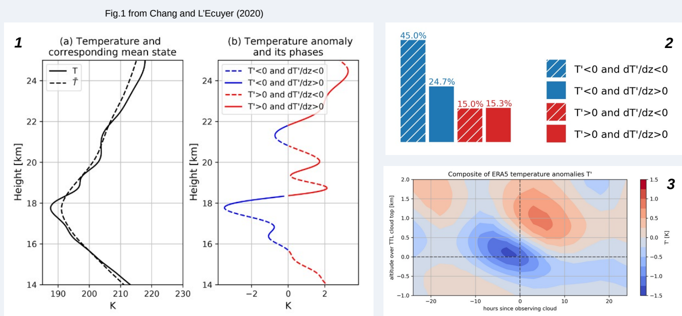
*A case study of collocated observations over a thin cirrus cloud. **a**: 11 µm brightness temperature map at coincidence; **b**: BeCOOL L1 curtain (along the solid line on the map); **c**: CALIOP L1 curtain (along the dashed line on the map); **d**, **e**: time series of brightness temperature under the balloon and the satellite; **f**, **g**: time series of optical depth τ above 16.5 km*



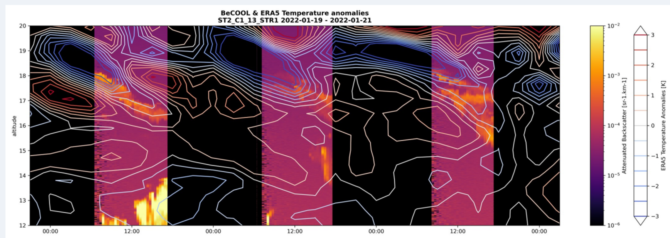
Distributions of cloud optical depth and cloud top altitude seen from BeCOOL and CALIOP during Strateole2 campaign. Clear cut-off at 2.10^{-3} in CALIOP's cloud optical depth distribution, with a perfect agreement between the two lidars above this threshold. 27% of BeCOOL's clouds have an optical depth lower than this threshold while it is below 1% for CALIOP. Those ultrathin clouds mainly exist in the TTL.

TTL cirrus and wave-induced temperature anomalies

Dynamical perturbations such as gravity waves trigger the in situ formation of TTL cirrus clouds by lowering temperatures enough for ice crystals to form and grow. BeCOOL's observations confirm results from recent studies about the distribution of clouds with respect to temperature anomalies : half of the TTL clouds are found in the cold and cooling phase of waves.



***1:** schematic of temperature anomalies profile and its phases ; **2:** distribution of BeCOOL cloudy lidar bins with respect to the 4 wave phases, (temperature COSMIC2) ; **3:** composite of ERA5 temperature anomalies (8-days rolling mean background removed) with respect to cloud top and cloud observation time.*



Three nights of BeCOOL cirrus observations with ERA5 temperature anomalies (8-days rolling mean background removed).

On-going work

- Characterizing the lifetime of TTL cirrus
- Microphysics simulations along backward/forward trajectories of air parcels initialized within and around observed clouds