Strateole 2: Investigating processes in the tropical tropopause layer with long-duration superpressure balloons

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Strateole 2 – Balloon Setup

Super Pressure Balloon
11m or 13m diameter - depending on configuration
- Float at constant density levels

Gondola “Euros”:
- Flight Monitoring/Control
- Scientific instrument: TSEN

Gondola “Zephyr”:
- Various combinations of up tp 3 scientific instruments
**Strateole 2 – Balloon Configurations**

**STR flight level ~20km**

**TTL flight level ~18km**

**STR1**
- TSEN
- BeCOOL: Backscattering lidar
- ROC: GPS RO
- BOLDAIR: radiometer

**STR2**
- TSEN

**TTL1**
- TSEN
- LOAC: particle counter
- SAWfPHY: water vapor
- B-BOP: Ozone

**TTL2**

**TTL3**
- TSEN
- LPC: particle counter
- RACHuTS: nighttime profiles of water vapor, temperature and particles down to 2km below balloon

**TTL4**
- TSEN
- B-BOP: Ozone
- Pico –SDLA: Water vapor and CO2

**TTL5**
- TSEN
- LOAC: particle counter
- SAWfPHY: water vapor
- FLOATS: continuous temperature profiles down to 2km below balloon
Strateole 2 – Balloon Launch
Strateole 2 – Previous Campaigns

Test campaign in 2019 (8 flights)
• Nov 2019 – Feb 2020
• Quasi-Biennial Oscillation (QBO) westerly phase at 20km

Science campaign in 2021 (17 flights)
• Oct 2021 – Jan 2022
• QBO transition westerly to easterly
To address dynamics, transport, microphysics, and dehydration processes as well as their interactions in the deep tropics

- Dynamics of the Tropical Tropopause Layer (TTL) and tropical lowermost stratosphere
  - Quasi-Biennial Oscillation
  - Planetary scale and gravity waves

- Climate effects of water vapor, thin cirrus and temperature variability in the TTL
  - Deep convection and tropical waves
  - Aerosols / cirrus ice particles
  - Profiles of water vapor, particles and temperature

- Satellite cal/val for ESA Aeolus 3D wind lidar

- Tropical forecast improvements
Challenges in representation of QBO in current GCMs:

• QBO is far too weak between 50hPa and 100hPa in most climate models (Bushell et al. 2020)
• Two disruptions in the cycle in the last 6 years suggest QBO may already be changing
• No consistency among GCMs on how QBO period will evolve in a warming climate

-> **Representation of tropical waves and parameterization of gravity wave drag are large sources of uncertainty in modelling QBO** (Holt et al. 2020, Richter et al. 2020)
Strateole 2 – Climatological Context

Stratospheric Water Vapor:
- Important greenhouse effect impacting surface temperatures
  - radiative impacts comparable to other greenhouse gases
- Global stratospheric concentrations are controlled by processes in the TTL
  - observed decadal variations in the water vapor are not understood

Tropical Waves:
- Drive Quasi-Biennial Oscillation (QBO)
- Influence transport of water vapor to the stratosphere across TTL
- Generate and modulate life-cycle of cirrus clouds

https://twitter.com/i/status/1173952942379917312
• Statistical analysis of momentum flux of convective gravity waves
• Dependence of momentum fluxes to distance to the nearest convective cell
• Wave amplitudes are highly intermittent and poorly represented in parameterizations (Alexander et al. 2021)
Can combine for the first time balloon-borne profiling measurements with horizontal balloon wind and temperature observations.
Analysis of fine-vertical scale waves that previously eluded observation and simulation in climate models and modern reanalyses

In the observed period these waves:

- Provided majority of forcing of QBO in lowermost stratosphere
- Controlled relative humidity and subvisible cirrus clouds occurrence through their temperature variations
Strateole 2 - Summary

• Data around the Equator

• Combination of high-resolution horizontal in-situ observations with vertical profiling measurements

• Unprecedented number of high-resolution profiles in the lowermost stratosphere, directly above the cold point

• Observation of global scale wave, gravity wave, and water vapor processes that are poorly represented in current GCMs and cannot be observed with current satellite technology
New measurements:
- Third campaign with 24 balloons planned in 2024

- New instruments:
  - dual-altitude temperature sensor (RATS)
  - Vertical Airspeed and Temperature Anemometer (VATA)

New analysis and applications:
- 3D wave analysis with balloon-borne radio-occultation measurements
- Development of new gravity wave parameterizations
- Improved QBO teleconnections in models