Strateole-2
First scientific campaign

Campaign summary and first scientific results

Edited October 2022

Using balloons to improve our understanding of the lower equatorial stratosphere

Strateole-2 scientific mission

To study the dynamic and microphysical processes responsible for the transport and drying of air masses in the upper troposphere / lower tropical stratosphere

To contribute to improving operational weather forecasting

To contribute to calibration-validation of space borne atmospheric science instruments

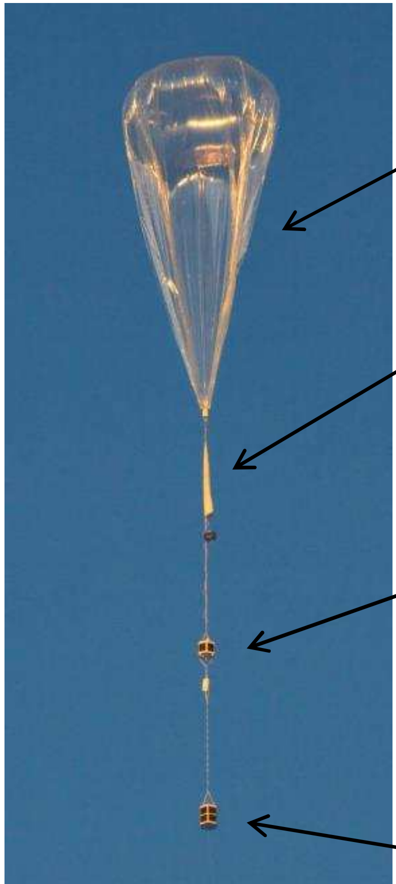
12 scientific instruments dispatched in 5 types of gondolas

Flights at 18 km and 20 km
Between 15° North and 20° South

Scientific data freely available to the international scientific community at the end of each campaign

Instrument	Purpose	Institute
GPS (Euros)	Wind (through position)	CNES
TSEN	Air Pressure and Temperature	CNRS-LMD
SAWfPHY	Water Vapor (through dew-point)	CNRS-LMD
B-Bop	Ozone Photometer	CNRS-LMD
LOAC	Optical Particle Counter	CNRS-LPC2E
pico-SDLA	Water Vapor and Carbon Dioxide (through light absorption)	CNRS-GSMA / DT-INSU
FLOATS	Local Profiler Air Temperature	LASP (USA)
LOPC	LASP Optical Particle Counter	LASP (USA)
RACHuTS	Local Profiler Air Temp., Water Vap., Cloud Detection	LASP (USA) & NOAA (USA)
BeCOOL	Nadir Cloud detection trough Long Distance Lidar	LATMOS / CNR France / Italy
ROC	Atm. Sounding through GPS Occultation High accuracy GPS position	Scripps Oceanography (USA)
BOL-DAIR	Up-Welling Infrared Flux	CNRS-LATMOS

Strateole-2 system overview



Spherical Super Pressure Balloon(1) , Helium
11 or 13 meter-Diameter, according to flight level and payload

Parachute

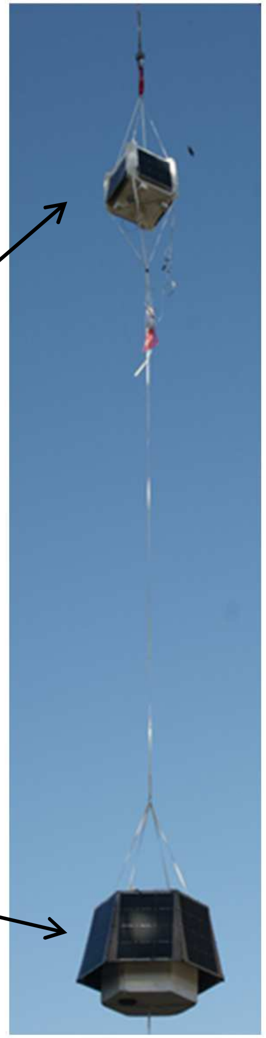
Gondola « EUROS », 13 kg : CNES
- Flight Monitoring / Control
- Scientific Instrument « TSEN »: CNRS-LMD

Control Center and operations : CNES

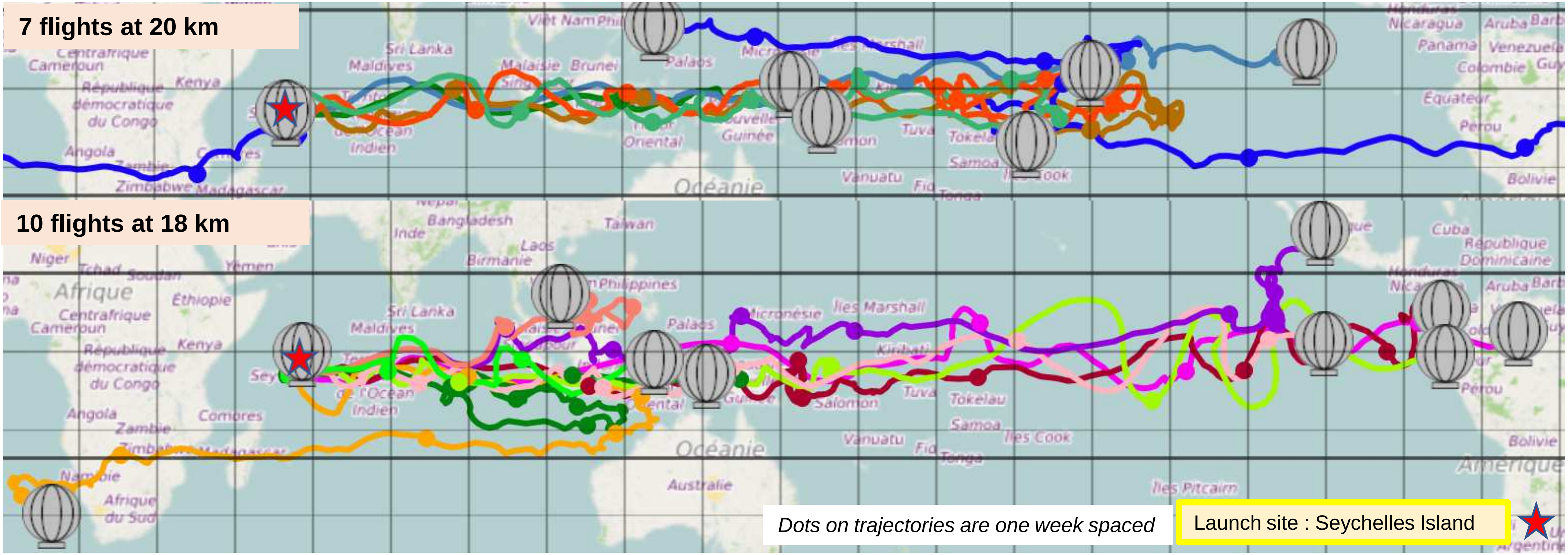
Gondola « ZEPHYR », 22kg
CNRS-LMD / LATMOS / Division Technique de l' INSU
- Various combinations of 2 to 3 scientific instruments

Science Mission Control Center : CNRS-LMD

(1) Here, in the early ascent phase. The balloon will reach its spherical shape once at float altitude



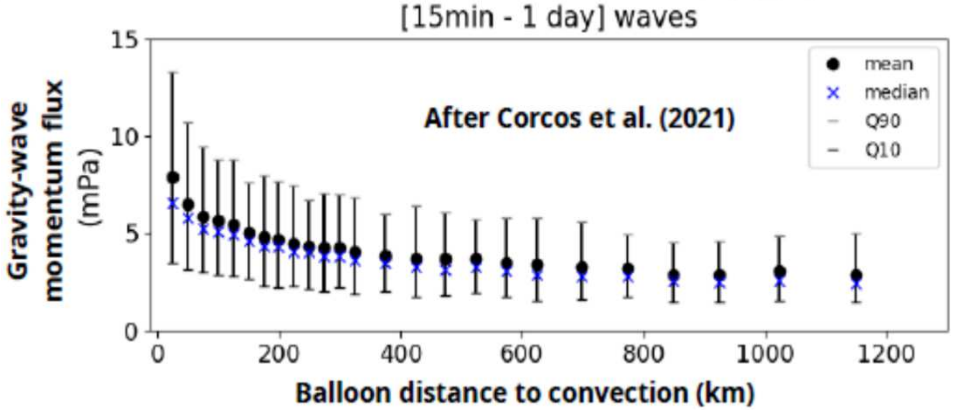
Balloons' trajectories

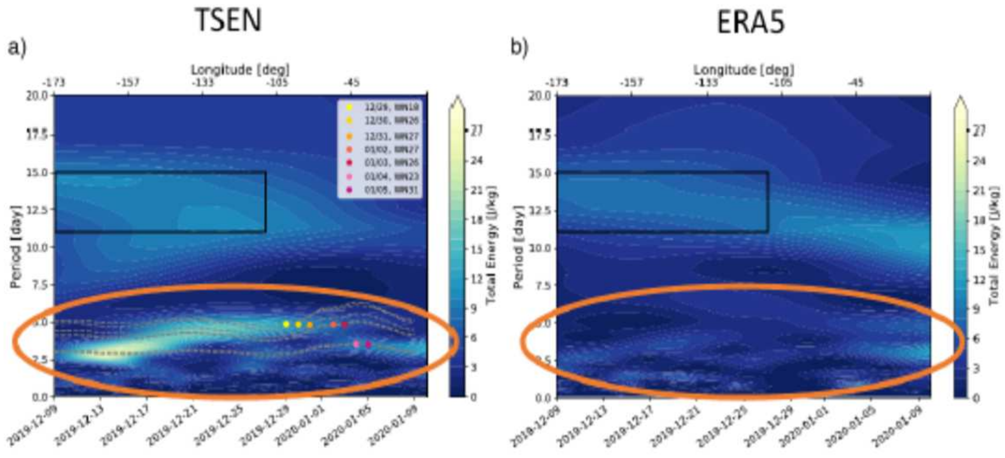


Launches from October 20 to November 26, 2021 from Seychelles island
Flights from October 20, 2021 to January 25, 2022
632 days of flight, mean of 37 days per balloon, longest flight : 71 days

Characterization of tropical waves

- **Short-scale gravity waves (intrinsic periods < 1 day) are mostly produced by convection**
  - Convective influence observed within 400 km of the convective system
  - Background gravity-wave activity observed far away from convection : other sources, lateral propagation ?
- **Identification of equatorially-trapped inertia gravity waves with intrinsic periods of 2-5 days**
  - Not represented in state-of-the-art numerical weather prediction models (example with ERA5 produced by ECMWF)
  - May provide a significant contribution to the driving of the Quasi Biennal Oscillation





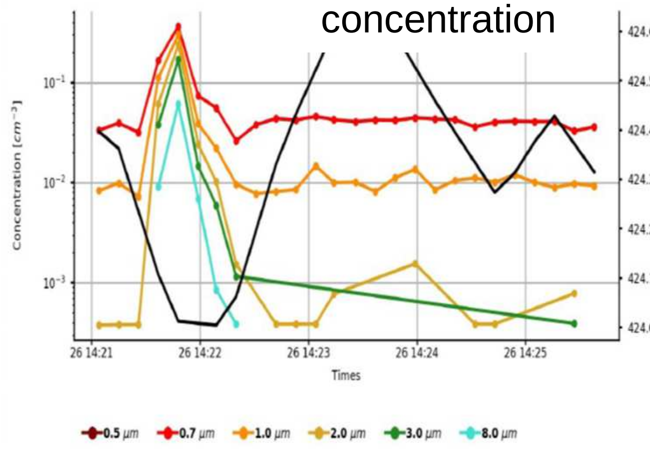
After Bramberger et al. (2022)

Corcos et al., Journal of Geophysical Research (2021)
Bramberger et al., Geophysical Research Letter (2022)
Cao et al., Atmospheric Chemistry and Physics (in press)

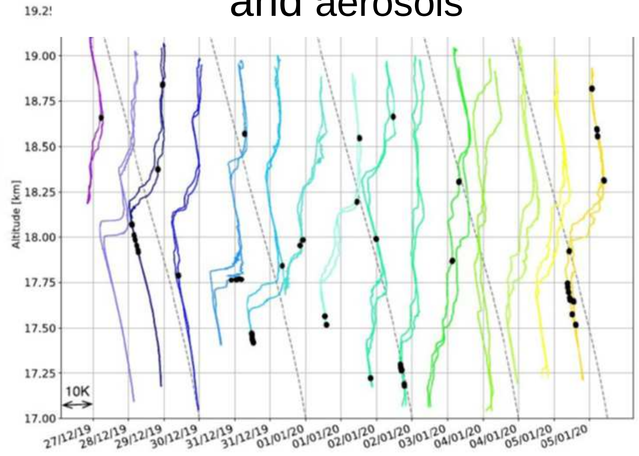
Particles in the lower stratosphere

- ❖ **Large particle occurrences in the lower stratosphere ?**
- ❖ **Detection of particles larger than 1 µm (cirrus-like) at altitudes higher than the climatological cold-point tropopause**
  - o Infrequent observations at balloon flight level (~18.5 km) with LOPC
  - o More frequent detection in RACHuTS profiles below the balloon

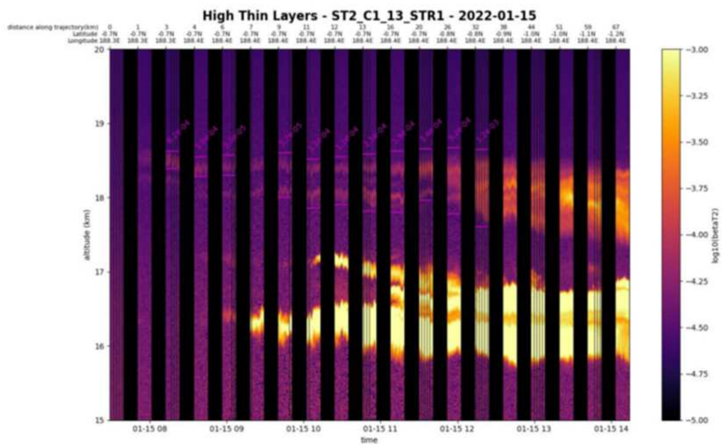
LOPC particle concentration



RACHuTS temperature and aerosols



- ❖ **Structures with similar characteristics (altitude, optical depth) observed in balloon-borne LIDAR observations**
  - o Wave-induced temperature disturbances triggering ice nucleation ?
  - o Other particles ?

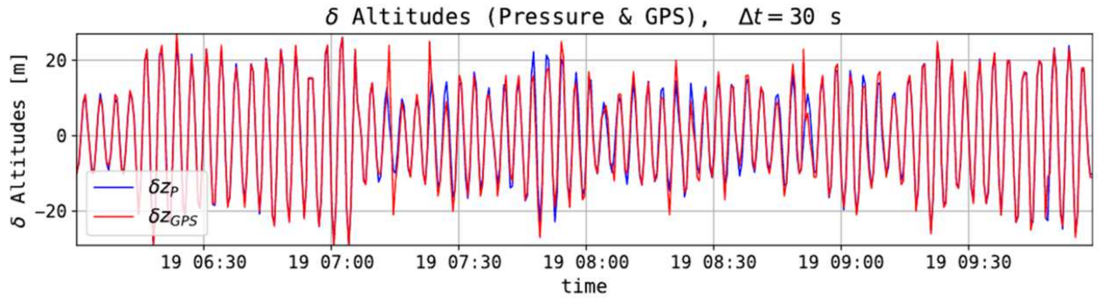


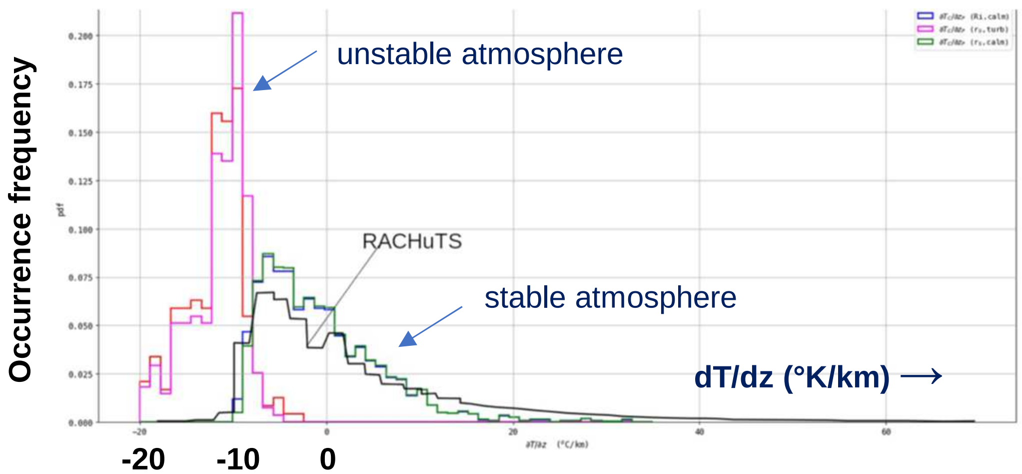
Kalnajs et al., Atmospheric Measurement Techniques (2021)

BeCOOL Lidar Attenuated backscatter

Atmospheric turbulence

- **Use of TSEN and balloon oscillations about its equilibrium density level to characterize gradient of (potential) temperature**
  - o Typical amplitude ~ 20 m
  - o Typical period ~ 3.5 minutes
- **Detection of near-/super-adiabatic layers**
  - o 5% of observations
  - o More frequent above convection
  - o Consistent with RACHuTS temperature profiles

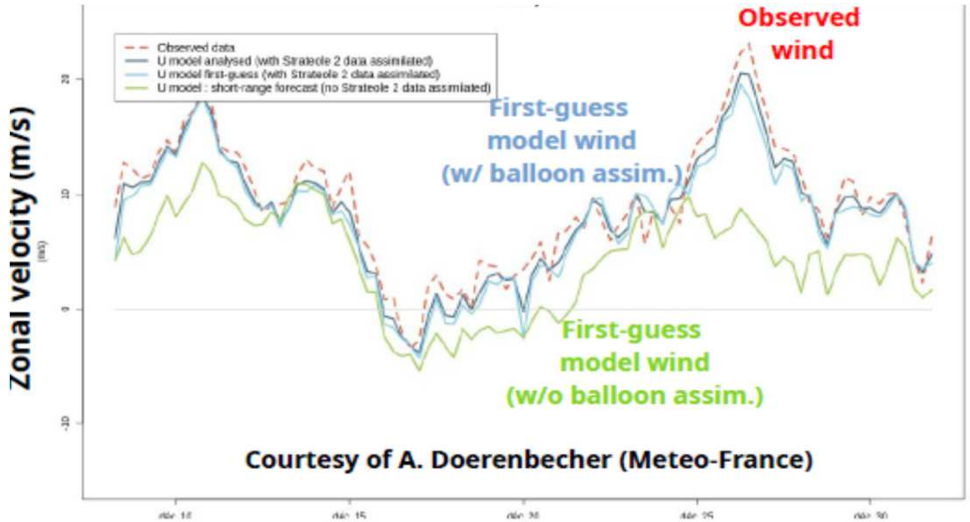


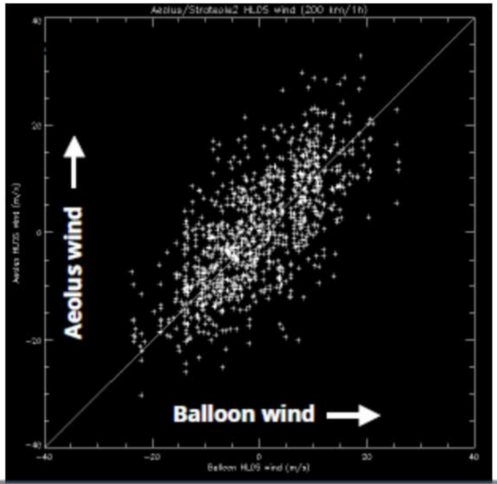


Wilson et al., Atmospheric Measurement Techniques & Discussions (2022)

Operational meteorology and satellite validation

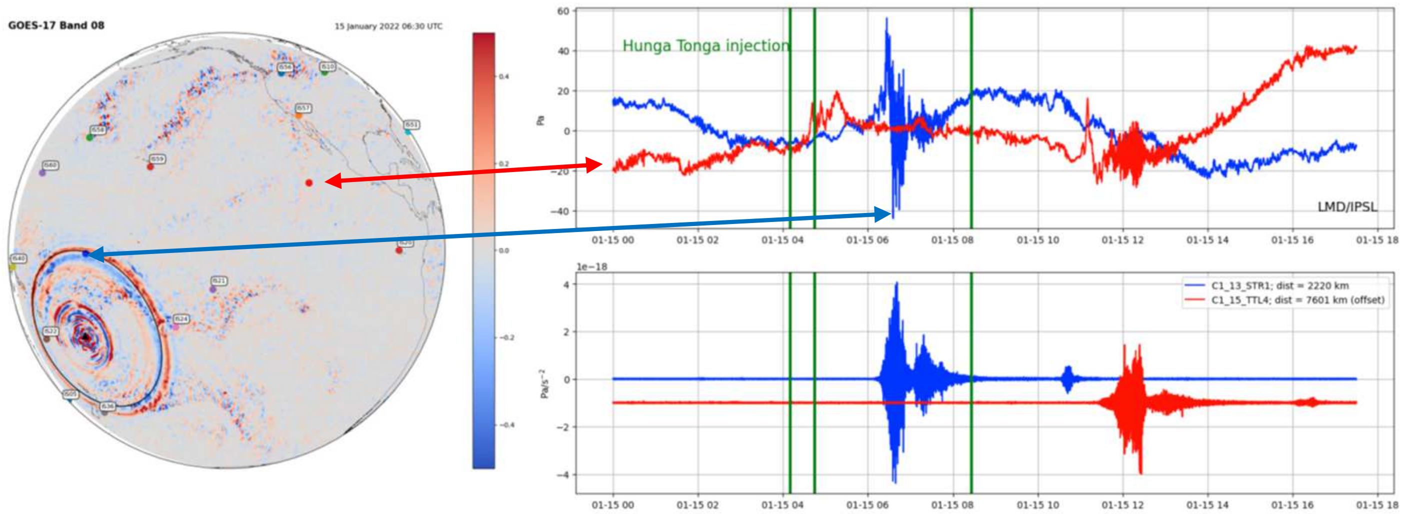
- **In-situ TSEN meteorological observations are processed and quality-checked in real-time during balloon flights**
- **These data are converted in appropriate format by Meteo-France and distributed to Numerical Weather Prediction (NWP) centers**
- **Meteo-France assimilated the balloon-borne observations from November 22, 2021 on**
  - TSEN observations contributed to improve the Arpège model circulation in the tropical lower stratosphere (in the same way than Aeolus)
- **Balloon-borne winds obtained during the 2019 campaign have also been used to validate the ESA Aeolus mission (first wind LIDAR in space)**



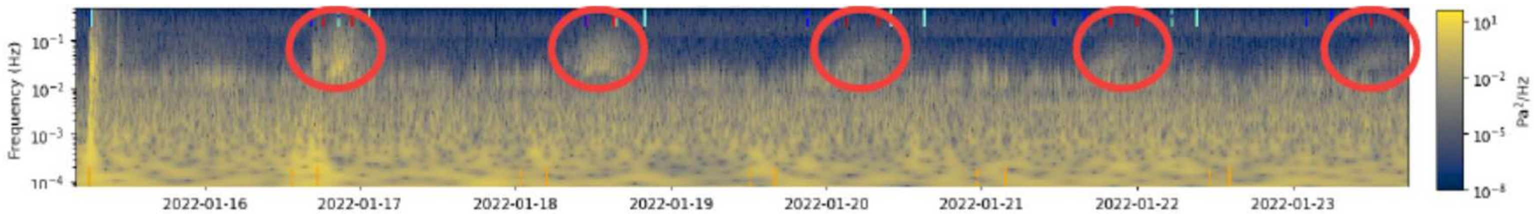


And apart the mission

- Two balloons were still in flight in early 2022 when Hunga-Tonga erupted
  - 2000 & 7000 km away
- TSEN Pressure measurements detected both the Lamb wave and the infrasound signals generated by the eruption
  - Multiple passes observed
- Earthquakes also detected => planetary applications



Garcia et al., Geophysical Research Letter (2022)
Podglajen et al., Geophysical Research Letter (in press)



Some pictures - release of the « 01_TTL5 » flight

Some research articles

- Haase, J., et al. Around the world in 84 days, Eos, 2018
- Hertzog A. How can we improve the driving of the Quasi-Biennial Oscillation in climate models?, J. Geopshys. Res.-Atmos. 2020
- Kalnajs, L. E., et al. A reel-down instrument system for profile measurements of water vapor, temperature, clouds, and aerosol beneath constant-altitude scientific balloons, Atmos. Meas. Tech., 2021
- Corcos, M., et al. Observation of gravity waves at the tropical tropopause using superpressure balloons. J. Geophys. Res.: Atmos., 2021
- Alexander, M. J., et al. Observational validation of parameterized gravity waves from tropical convection in the Whole Atmosphere Community Climate Model. J. Geophys. Res.: Atmos, 2021
- Bramberger, M., et al. First Super-Pressure Balloon-Borne Fine-Vertical-Scale Profiles in the Upper TTL: Impacts of Atmospheric Waves on Cirrus Clouds and the QBO. Geophys. Res. Lett., 2022
- Garcia, R. F., et al. Infrasound from large earthquakes recorded on a network of balloons in the stratosphere, Geophys. Res. Lett., 2022
- Podglajen, A., et al. Stratospheric Balloon Observations of Infrasound Waves From the 15 January 2022 Hunga Eruption, Tonga, Geophys. Res. Lett., 2022
- Cao, B., et al. Equatorial waves resolved by balloon-borne Global Navigation Satellite System Radio Occultation in the Strateole-2 Campaign, Atmos. Chem. Phys., in press.

To be continued …

Flight Validation Campaign, (8 flights), « Pre-Strateole2 »

- Winter **2019-2020** (launches : Nov 1st / mid-Dec 2019)

First Science Flight Campaign (17 flights), « Strateole2-SC1 »

- Winter **2021-2022** (launches : mid-Oct / mid-Dec 2021)

Second Science Flight Campaign (20 flights), « Strateole2-SC2 »

- Winter **2025-2026** (launches : mid-Oct / mid-Dec 2025)

Contacts :

Stéphanie Venel, CNES, balloon project manager, stephanie.venel@cnes.fr
Albert Hertzog, LMD, principal investigator, albert.hertzog@lmd.ipsl.fr