Funded by the Horizon 2020 framework program of the European Union

HEMERA WORKSHOP

CNES Balloon Program

André Vargas (CNES)

(Rome, July 4rd - 6th , 2022)

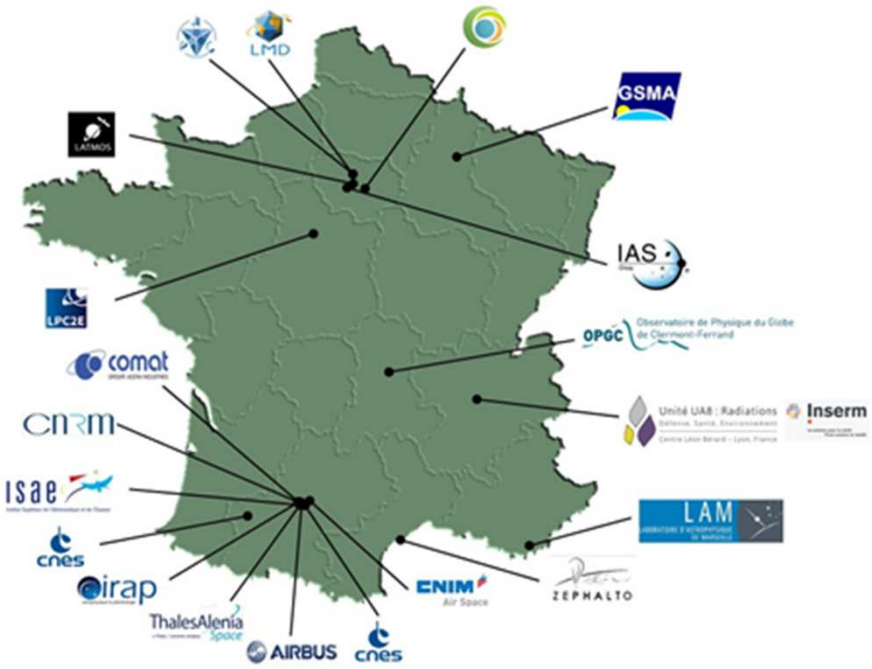
The CNES Balloon Program

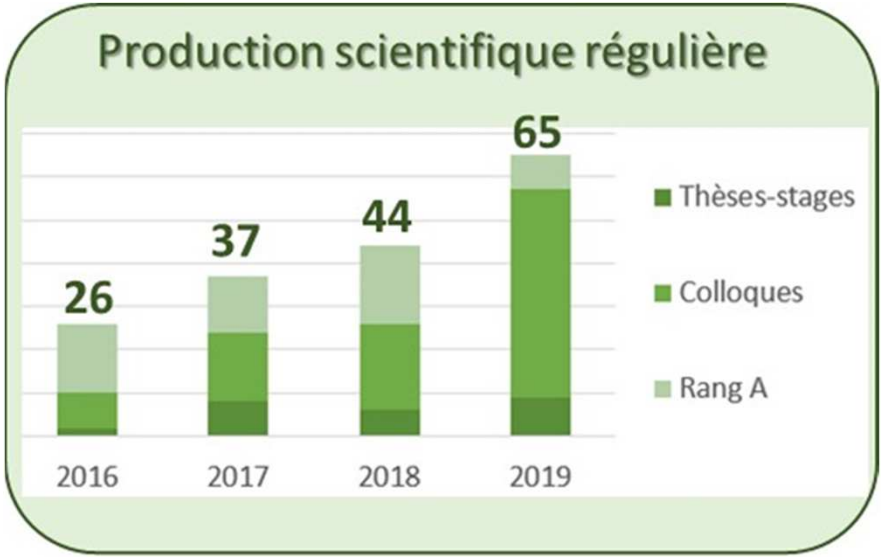
SUMMARY

- The French Balloon Science Program & its major scientific issues
- Balloon science outings
- Balloons projects and prospects
- The technical and operational infrastructure

French Laboratories Driving Balloon Activities

❖ **15 French laboratories implied in scientific balloon activities**





French Balloon Program & Major Scientific Issues

Fields of application

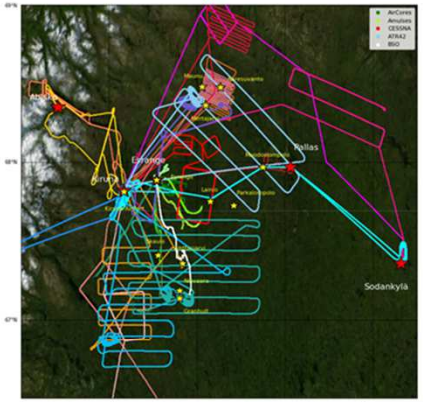
- Scientific research areas: ocean-atmosphere, astronomy-astrophysics, solid-Earth-solid, but also life sciences, physics particle
- Satellite demonstrators
- Calibration and validation of satellite's instruments
- Technological developments (HASP technologies, solar cells, etc.)

Scientific issues of ocean-atmosphere science

- Essential climate variables
- Greenhouse gases
- Reactive species, ozone, halogenated compounds
- Water vapor, aerosols
- Atmospheric dynamics
- Gravity waves, Brewer Dobson circulation, QBO, mixing through barriers
- Atmosphere radiative balance (OLR-OSR)
- Impact of volcanism, primitive atmosphere
- Atmospheric electricity

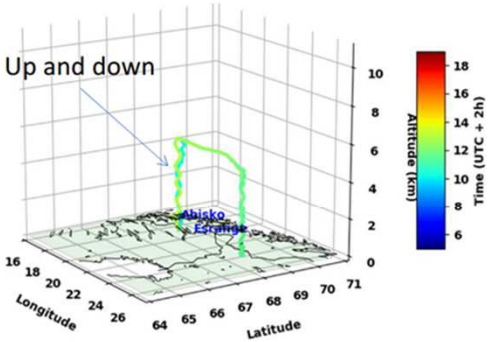
MAGIC: Monitoring of Atmospheric composition and Greenhouse gases through multi-Instruments Campaigns (C. Crevoisier & All)

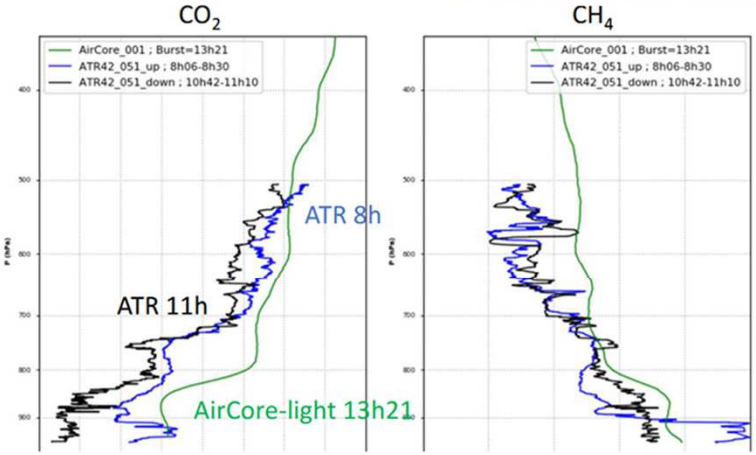
Vectors			Instruments		Team	Observation
Balloons	Weather balloons (BLD) @Esrange		AirCore-light	5	LMD	0-30 km profiles (CO_2, CH_4, CO, N_2O, T, H_2O, wind)
			Amulse	5	GSMA	0-30 km profiles (CO_2, CH_4, H_2O, T)
	W. balloons @ Sodenkylä		AirCore	-	FMI/RUG	0-30 km profiles (CO_2, CH_4, CO, T, H_2O, wind)
	Stratospheric Balloons (BSO) *SUPER CLIMAT @ Esrange*		AirCore-HR	1	LMD	0-30 km profiles (CO_2, CH_4, CO, T, H_2O, wind + *C isotopes*, N_2O)
			AirCore-light	2	LMD	
			Amulse	1	GSMA	0-30 km profiles (CO_2, CH_4, H_2O, T)
			SAMPLE	1	GSMA	0-30 km profiles at a few points (CO_2, CH_4, H_2O, T)
			SPECIES	1	LPC2E	0-30 km profiles of many trace gases at ppt level
Ground	FTS		CHRIS	1	LOA	Weighted columns XCO_2, XCH_4, XCO, etc.
			EM27/SUN	5-6	CNESx1, GSMAx1, LERMAx1, FMIx1, KITx1, UoLx1	
	In-situ		Picarro	3	LMDx2, LSCEx1	In-situ concentration of CO_2, CH_4, CO
Aircrafts	SAFIRE ATR42	In-situ	Picarro	2	SAFIREx1, LSCEx1	In-situ concentration of CO_2, CH_4, CO
			SPIRIT	1	LPC2E	In-situ concentration of NO_y, CH_4, CO
		Lidars	CHARM-F	1	DLR	Weighted columns XCO_2, XCH_4
			LIVE	1	ONERA-DOTA	Wind profile
	DLR Cessna In-situ		Aerodyne Dual QCLS		DLR	In-situ concentration of CO_2, CH_4, CO
			MetPod		DLR	T, H_2O, 3D-wind
			Flask sampler		DLR	CH_4 isotopes
	Twin Otter		HyTES		NASA/JPL	CH_4 surface
			SPECIM		KCL	



AirCores
Amulse
BSO
Cessna
ATR42
Stations
Mobile FTS

Missing:
- AirCore from Sodank
- Twin Otter

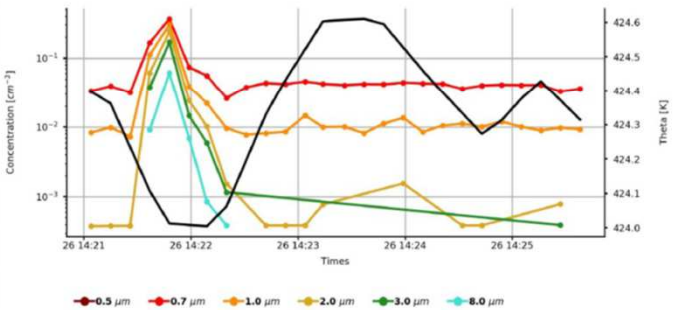


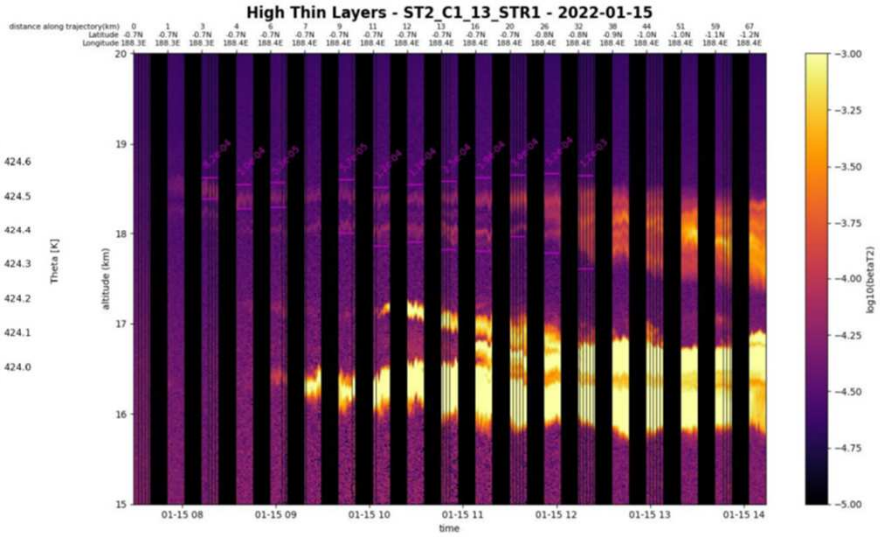


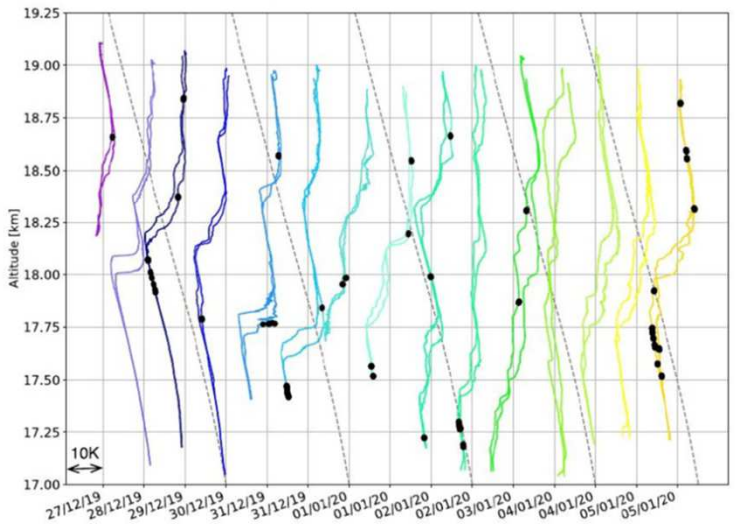
❖ **High synergies of combined campaigns: aircraft, balloon and ground instrumentation**

Strateole-2 (1/3)

Detection of particles larger than 1 µm (cirrus-like) at altitudes higher than the climatological cold-point tropopause (A. Herzog & All)







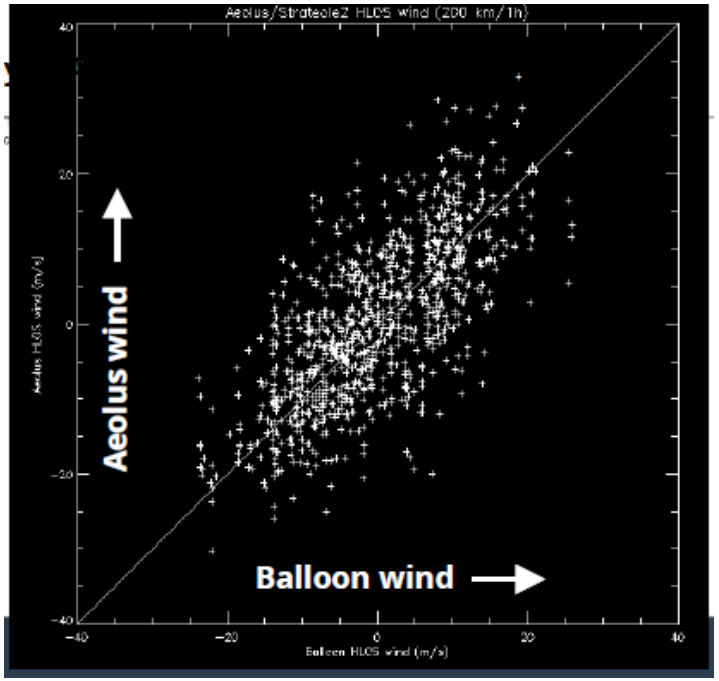
LPC particle concentration

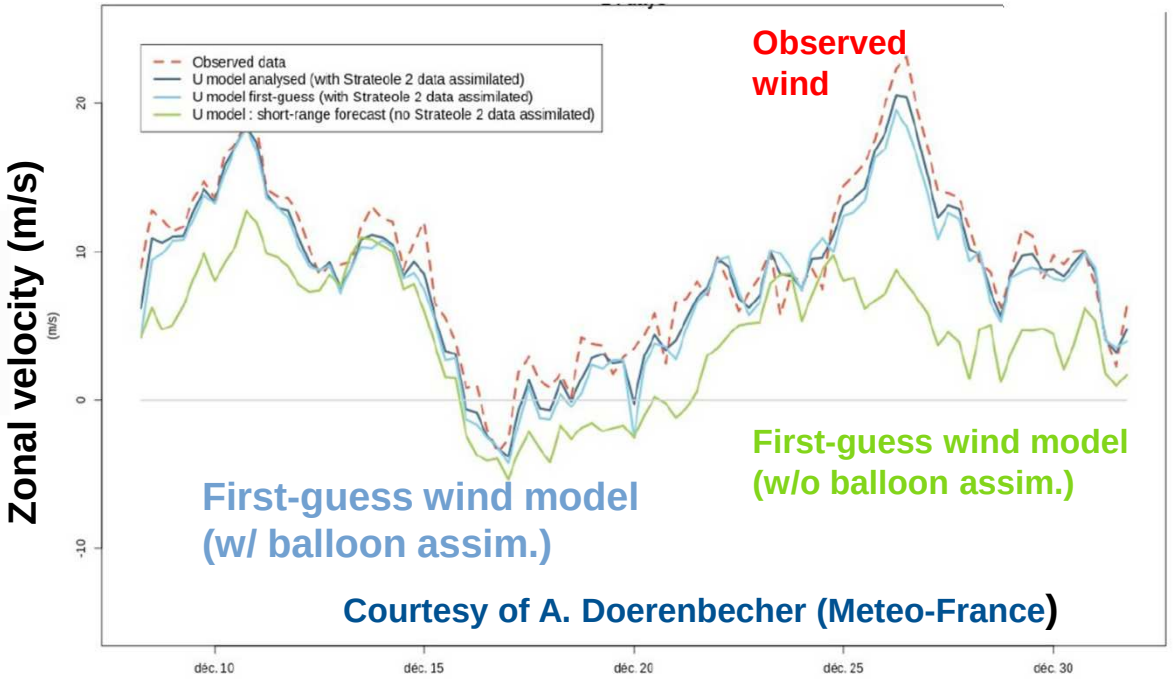
BeCOOL Lidar attenuated backscatter

RACHuTS temperature and aerosols

Strateole-2 (2/3)

❖ Operational meteorology and satellite validation (A. Herzog & All)



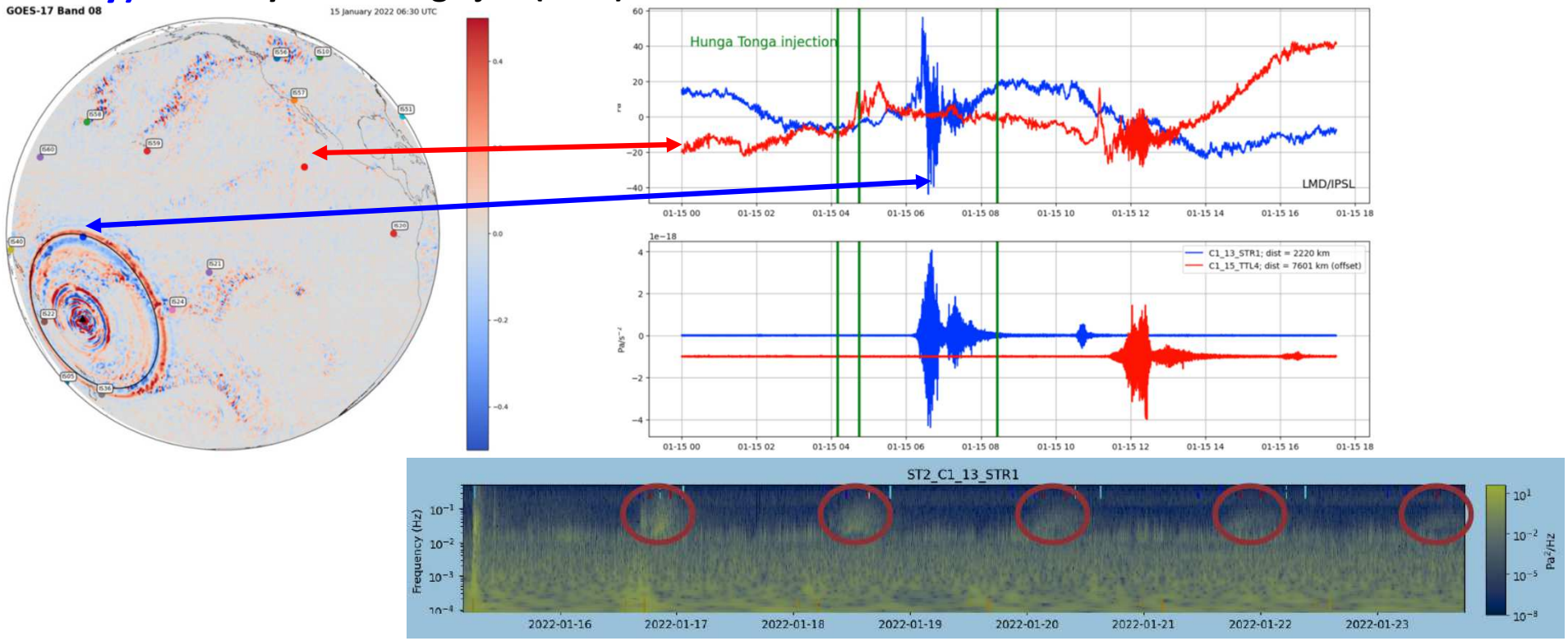


Courtesy of A. Doerenbecher (Meteo-France)

- Balloon-borne winds obtained during the 2019 campaign have also been used to validate the ESA Aeolus satellite mission (first wind lidar in space)
- In-situ TSEN meteorological observations are processed and quality-checked in real-time during balloon flights
  - Data distribution to NWP centers
  - Improvement of Arpège model circulation in the tropical lower stratosphere

Strateole-2 (3/3)

Two balloons were still in flight in early 2022 when Hunga-Tonga erupted (2000 & 7000 km away) Courtesy of A. Podglajen (LMD)



- TSEN Pressure measurements detected both the Lamb wave and the infrasound signals generated by the eruption (multiple passes observed)
- Earthquakes also detected => planetary application

XENON: Primitive Atmosphere

❖ **Understanding of terrestrial xenon leakage**

(M. Moreira, E. Nuñez Guerrero - ISTO/OSUC)

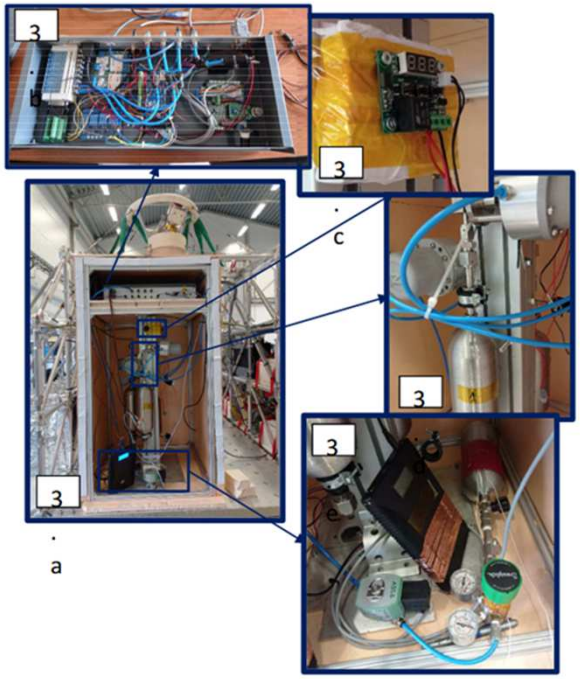
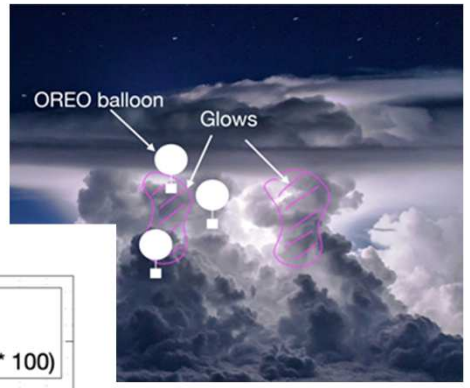


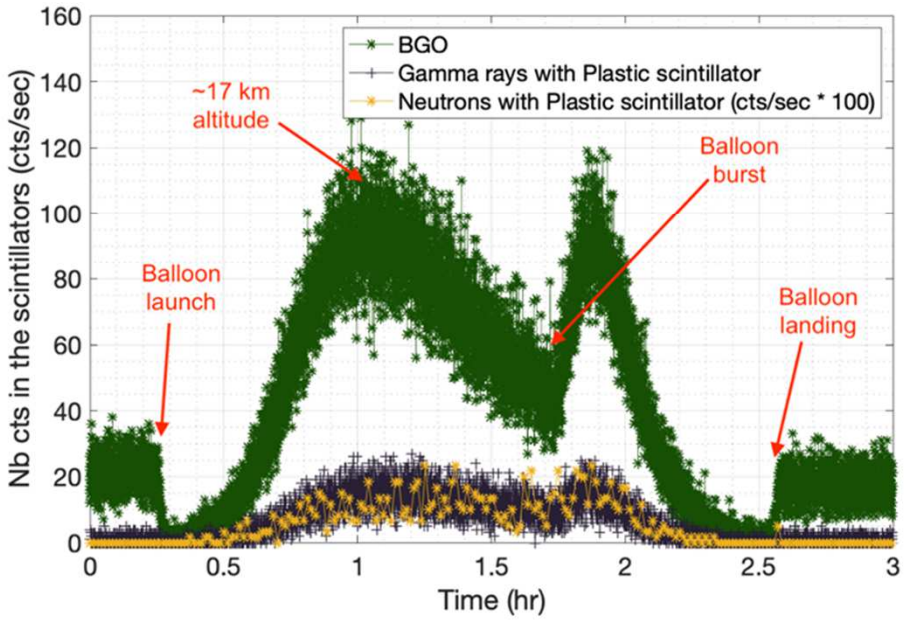
Figure 3a. Sampling device. **3b.** Electronic system. **3c.** Thermal system lector. **3d.** Pneumatic valves and sampling bottles. **3e.** Air compressed bottle, battery, and electric valve.

OREO : Atmospheric Electricity

❖ **Radiation measurements during thunderstorm (X-Storm)**

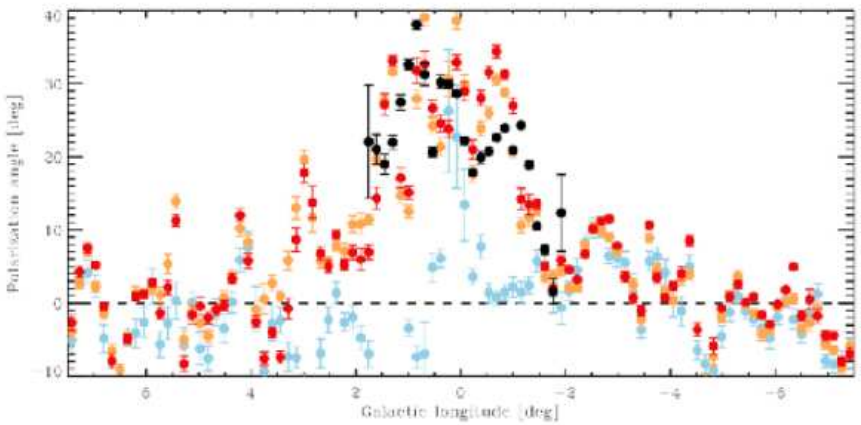
(S. Celestin - LPC2E)

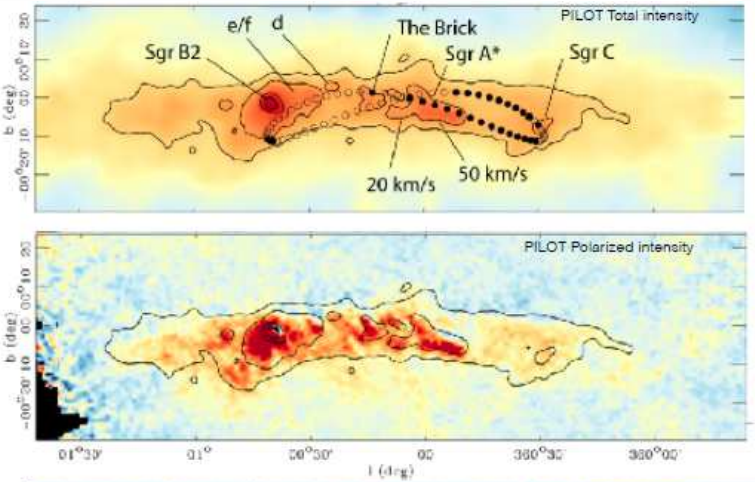


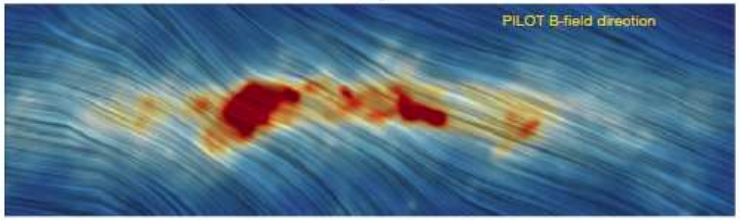


Gamma ray and neutron profiles in the atmosphere.

Astrophysics - First Results of Pilot Flight#2







Cloud	$\log(n_{H_2})$ (cm^{-3})	δv_{LOS} ($km\,s^{-1}$)	B_{equ} (mG)
Sgr B2	5.0	20	3.9–5.8
50 $km\,s^{-1}$	4.5	10	0.3–1.7
20 $km\,s^{-1}$	4.3	10	0.5–1.2
Brick	4.2	5	0.2–0.5

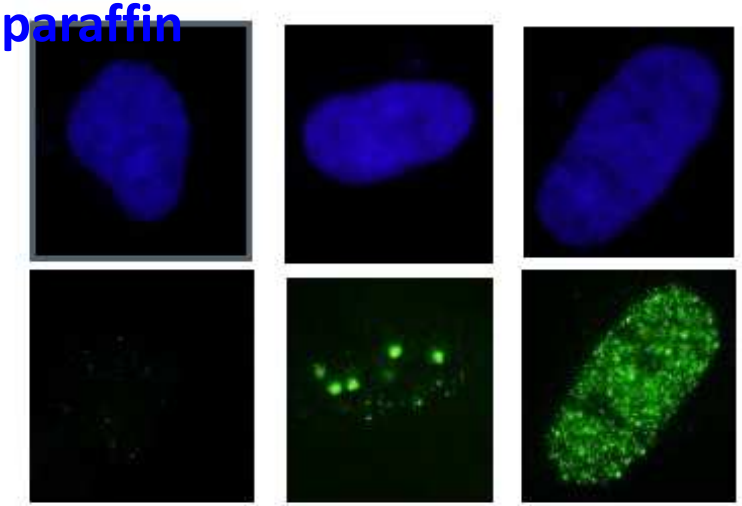
Mangilli et al. A&A 630, A74 :

- **The B-field traced by dust follows the twisted torus of the Central Molecular zone**
- **The direction is globally consistent with that seen with Planck (tilt of 22°)**
- **The higher resolution of PILOT allows to measure it down to GMC scales**
- **The magnetic field inferred for several GMCs is surprisingly strong: ~1 mG**

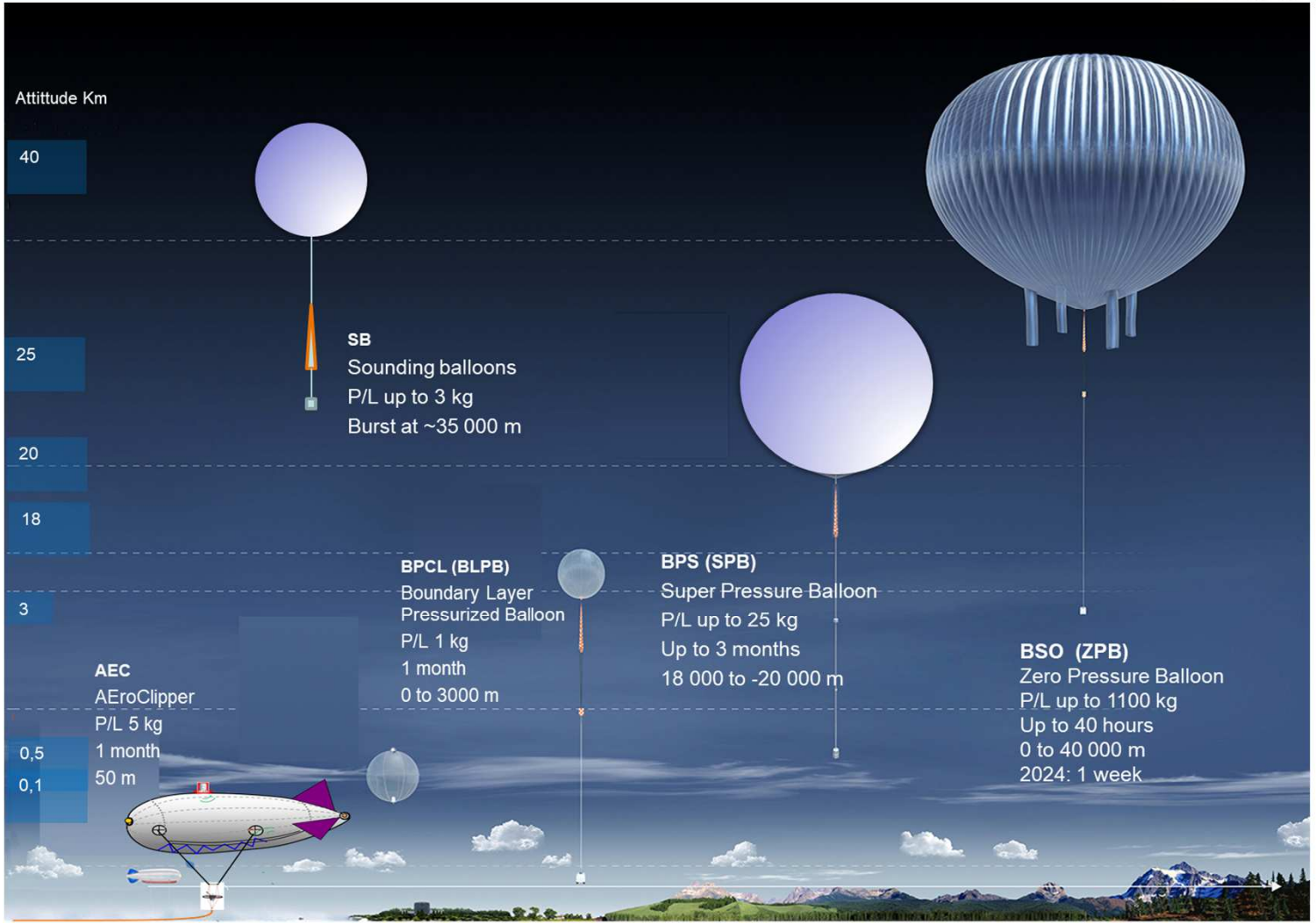
Life Science - First Results of Bernadotte Projects

See N. Foray & J. Restier--Verlet

- 6 cultured human cell lines exposed to radiation in the stratosphere
  - Fibroblasts Radio-resistant skin, Radiosensitive skin Human-Osteoblasts
  - Heart Fibroblasts, Heart Myocytes, Human Crystalline Epithelium
- 8 shields
  - Wood, wood + paraffin , regolith 1, regolith 2, Aluminum, Aluminum / Kevlar , Aluminum / Kevlar /aluminum, Lead, Lead + paraffin
- THAT IS
  - 600 different conditions
  - 1200 slides
  - 96000 cores read
  - 4 months of reading



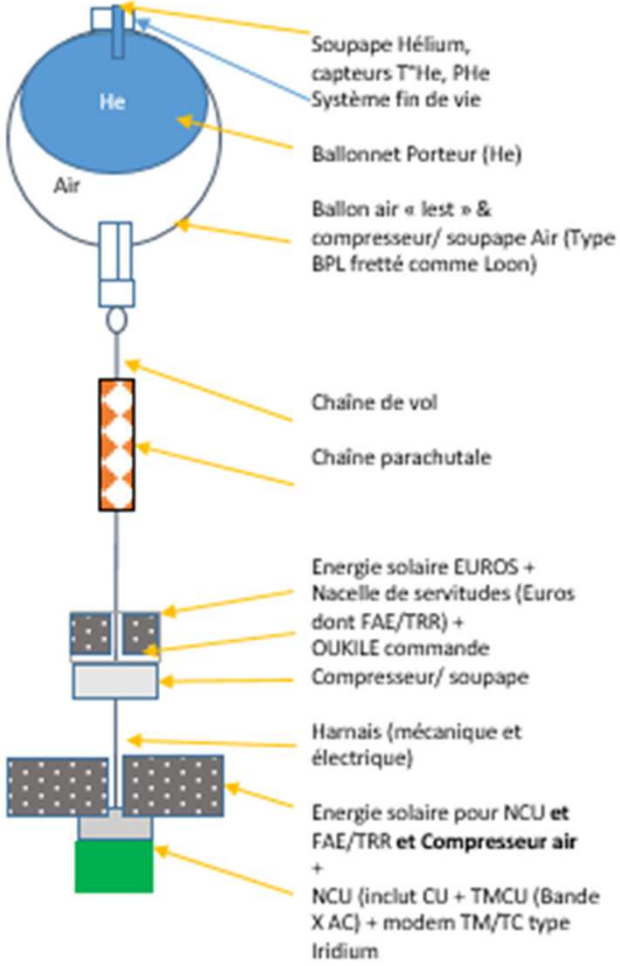
CNES Balloon Vehicles



SPS's Development: The Maneuvering Balloon

- Project developed with CNIM AS (manufacturer of CNES balloons) & Airbus Space & Defense
- 2022: System Definition
  - Bi-balloon vehicle, based on 'pumpkin' pressurized balloon with an internal helium balloon
  - Re-use of SPS avionics & subsystems
- 2023: Ground qualification
  - Critical subsystems: compressor, valves, avionics, ..
  - The technique of balloon launching
- 2024: In fight demonstration (Strateole-2 campaign)

Ex.: Google-Loon Trajectories



CNES Objective for Balloon Activities in Brazil

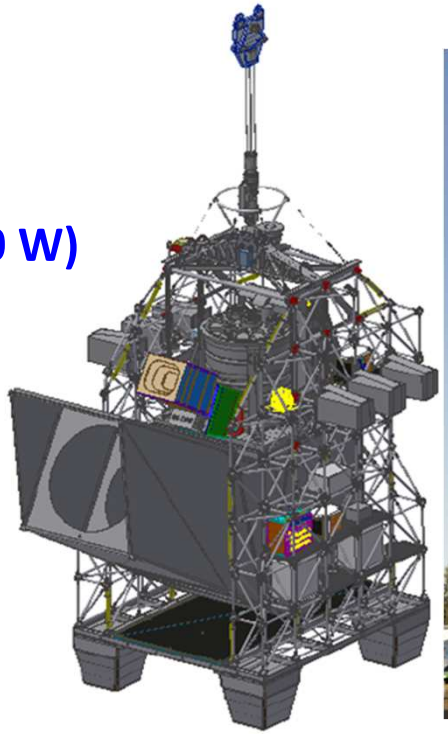
- Objective: new launch site, meeting the following requirements
  - Scientific constraint: latitude between 0° South and 10° South
  - Availability: More than 20 years
  - Safety constraint: population density less than 1 inhabitant per km²
    - Bauru & Sao Jose (AEB Balloon Facilities): too much South
    - Teresina: Too much population at this latitude (East and West)
    - Tocantins area can be an option
- Three launch sites to study
  - Pau do Ferros (Rio grande do Norte)
    - AEB proposal
  - Palmas (Tocantins)
    - cnes proposal
  - Balsas (Maranhão)
    - New cnes proposal for analysis

The first launch campaign with ZPS (and possibly other types of balloons) is scheduled for no earlier than 2025 or 2026

Scientific Gondola/Platform: On-Board Services

A service-oriented architecture

- Science TM &TC communication links
  - RF S-Band: 1Mbps & 50 kbps
  - Satellite: >= 100 kbits/s (2023)
- Thermal control of the gondola
- Power supply distribution ~ 1 kW, solar energy (4 x 350 W)
- Diurnal stellar sensor: ESTADIUS
- Pointing performances
  - Azimuth coarse pointing: stability ~ 1'
  - 2 axes fine pointing: accuracy < 1''



Customers/ partners, users:

- French labs via National Program
- European payloads from HEMERA (H2020)
- Canadian payloads (CSA/CNES agreement)
- Technologic, academic, institutional or industrial payloads: billing or agreement

The Balloon Operational Infrastructure: The Campaigns

Zero Pressure Balloon (ZPB): annual campaign

- ❖4-5 flights: Klimat 2021, STRATO Science 2022, …
- ❖~15 French and international payloads
- ❖Launch sites: Kiruna (68N), Timmins (48N), Alice Springs (24S), …

Super Pressure Balloons (SPS): 1 campaign every 3-5 years

- ❖Long duration flights
- ❖Strateole-2 validation: 8 flights, Nov. 2019- Feb. 2020
- ❖1st scientific campaign: 17 flights, Oct. 2021- Jan. 2022

Sounding Balloon (SB) campaigns

- ❖ All year round, from Aire sur l'Adour
- ❖ During ZPB campaign (MAGIC 2021)
- ❖ Projects/payloads: MAGIC, Oreo, AirCore, LOAC, AMULSE, POC Startups, Universities …

Dedicated campaigns

- ❖ FIREBall: CNES pointing gondola launched by NASA

The Balloon Operational Infrastructure: The Prospects

Zero Pressure Balloon (ZPB): annual campaign

- ~15 French and international payloads
- Timmins 2022 & 2023, Kiruna 2024, ..
- Transatlantic flight: 6 days duration in 2024
- New equatorial launching site in Brazil (2025), …

Super Pressure Balloons (SPS): 1 campaign every 3-5 years

- Long duration flights
- 2nd scientific campaign: 20 flights, Oct. 2024- Jan. 2025
- 1st flight of Maneuvering Super Pressure Balloon: 2024

Sounding Balloon (SB)campaigns

- All year round, from Aire sur l'Adour
- Aire sur l'Adour: reference stations for Green House Gases measurements (SB flights & ground instrumentation)


Thanks for your attention,
questions ?